



The objective of this project is to design the test equipment that will be responsible for verifying the correct operation of the boards developed within the company, and their integration within the government satellites SPAINSAT NG I and SPAINSAT NG II. This document will present the work carried out by the author during his training internship in the company Tecnobit-Grupo Oesía, which lasted 7 months.



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# UNIVERSITY OF GRANADA

## Bachelor Degree in Telecommunications Technology Engineering



### Bachelor Thesis

# Test Equipment Design for a Space System

Miguel Romero García  
Academic year 2020/2021

Tutor: Andrés María Roldán Aranda

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**“Test Equipment Design  
for a Space System”**





BACHELOR DEGREE IN  
TELECOMMUNICATION ENGINEERING

Bachelor's Thesis

*“Test Equipment Design  
for a Space System”*

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Miguel Romero García





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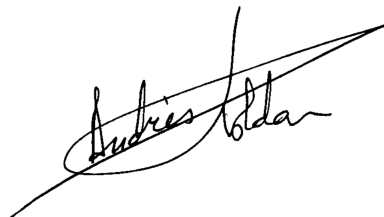
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# Test Equipment Design for a Space System

Miguel Romero García

## **KEYWORDS:**

Electrical Ground Support Equipment, PCB Design, European Cooperation for Space Standardization, SolidWorks®, RFCB, MCCM, DL.

## **ABSTRACT:**

The aim of this project is to show the work carried out by the author during his work experience at the company Tecnobit-Grupo Oesia, where he has been in charge of the design of the test equipment that will be responsible for verifying the operability of the distribution electronics developed at the company for the SPAINSAT NG I and SPAINSAT NG II satellites.

During the development of this document, we will start by explaining how a space system is developed, followed by the requirements agreed with the different companies involved in the project, and later, with the design of the EGSE developed at the company by the author. Once finished, the implementation process will be shown, as well as the budget that accompanies this part of the project.









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# Index

Defense authorization	vii
Library deposit authorization	ix
Abstract	xi
Dedication	xiii
Acknowledgments	xv
Index	xvii
List of Figures	xxiii
Glossary	xxxiii
Acronyms	xxxv
<b>1 Introduction</b>	<b>1</b>
1.1 State of the art: Spainsat NG Proyect . . . . .	2
1.2 Motivation . . . . .	3
1.2.1 Personal motivation . . . . .	3
1.2.2 Proyect motivation . . . . .	3

1.3	Objectives . . . . .	4
1.4	Methodology . . . . .	8
1.5	Project Structure . . . . .	9
1.6	Time management . . . . .	9
<b>2</b>	<b>Space Systems</b>	<b>11</b>
2.1	Phase 0: Mission analysis/Needs identification . . . . .	12
2.2	Phase A: Feasibility . . . . .	13
2.3	Phase B: Preliminary definition . . . . .	13
2.4	Phase C: Detailed definition . . . . .	13
2.5	Phase D: Qualification and production . . . . .	16
2.6	Phase E: Operations/Utilization . . . . .	16
2.7	Phase F: Disposal . . . . .	17
<b>3</b>	<b>EGSE Requirements</b>	<b>19</b>
3.1	Use cases . . . . .	20
3.2	Requirements for the functions and performance of the system . . . . .	31
3.2.1	EGSE BOARDS . . . . .	31
3.2.2	SPAINSAT NG BOARDS . . . . .	32
3.2.3	EGSE SW . . . . .	32
3.2.4	REPORTING . . . . .	32
3.3	External system interface requirements . . . . .	33
3.3.1	RFCB . . . . .	33
3.3.2	DL . . . . .	35
3.4	Safety requirements . . . . .	37
3.5	Security and privacy requirements . . . . .	38
3.6	Human-factors engineering requirements . . . . .	38
3.7	Operations and maintenance requirements . . . . .	38
3.8	System interface requirements . . . . .	38

3.8.1	System external interfaces . . . . .	38
3.8.2	Egse communications interface . . . . .	38
3.8.3	Egse mechanical interface . . . . .	38
3.8.4	Egse electrical I/O interface . . . . .	39
3.9	System environmental requirements . . . . .	39
3.10	Internal data requirements . . . . .	39
3.11	Physical requirements . . . . .	39
3.12	Personal-related requirements . . . . .	39
<b>4</b>	<b>EGSE DESIGN</b>	<b>41</b>
4.1	EGSE boards . . . . .	41
4.1.1	EIM BOARD . . . . .	42
4.1.2	DB DUMMY . . . . .	46
4.1.3	MCCM DUMMY . . . . .	48
4.2	EGSE mainframe . . . . .	51
4.2.1	EIM BOX . . . . .	53
4.2.2	EGSE BOARDS POWER SUPPLIES . . . . .	55
4.2.3	UUTs POWER SUPPLIES . . . . .	71
4.2.4	DIN-RAIL . . . . .	82
4.2.4.1	USB-SPI . . . . .	82
4.2.4.2	USB-DIOs . . . . .	84
4.2.4.3	SWITCH ETHERNET . . . . .	85
4.2.4.4	HUB-USB . . . . .	87
4.2.4.5	POWER SUPPLY . . . . .	89
4.2.4.6	DIN-RAIL . . . . .	91
4.2.5	LAPTOP . . . . .	93
4.2.6	POWER PROTECTION UNIT (PPU) . . . . .	94
4.2.6.1	CIRCUIT BREAKER . . . . .	99

---

4.2.6.2	DIFFERENTIAL SWITCH . . . . .	100
4.2.6.3	EMERGENCY STOP BUTTON . . . . .	102
4.2.6.4	RELAY . . . . .	103
4.2.6.5	GENERAL SWITCH . . . . .	105
4.2.7	POWER STRIP . . . . .	107
4.2.8	RACK SIZE . . . . .	108
4.3	EGSE diagram . . . . .	109
4.4	EGSE CABLES . . . . .	112
4.4.1	COTS . . . . .	112
4.4.1.1	W14 . . . . .	113
4.4.1.2	W16 . . . . .	113
4.4.1.3	W17 . . . . .	114
4.4.1.4	W18 . . . . .	114
4.4.1.5	W19 . . . . .	115
4.4.1.6	W20 . . . . .	116
4.4.1.7	W21 . . . . .	117
4.4.1.8	W22 . . . . .	117
4.4.1.9	W23 . . . . .	119
4.4.1.10	W24 . . . . .	120
4.4.1.11	W25 . . . . .	120
4.4.1.12	W26 / W35 / W36 . . . . .	120
4.4.1.13	W27 . . . . .	122
4.4.1.14	W28 . . . . .	122
4.4.2	TBT . . . . .	123
4.4.2.1	CABLES EXT . . . . .	129
4.4.2.1.1	W01 . . . . .	129
4.4.2.1.2	W03 . . . . .	148
4.4.2.1.3	W05 y W06 . . . . .	152



4.4.2.1.4	W08 . . . . .	156
4.4.2.1.5	W50 . . . . .	160
4.4.2.2	CABLES INT . . . . .	164
4.4.2.2.1	W09 . . . . .	164
4.4.2.2.2	W10 . . . . .	167
4.4.2.2.3	W11 . . . . .	170
4.4.2.2.4	W12 . . . . .	174
4.4.2.2.5	W13 . . . . .	180
4.4.2.2.6	W15 . . . . .	183
4.4.2.2.7	W34 . . . . .	187
4.5	EIM BOX front design . . . . .	192
<b>5</b>	<b>EGSE Implementation</b>	<b>195</b>
<b>6</b>	<b>Budget</b>	<b>209</b>
<b>7</b>	<b>Bibliography</b>	<b>219</b>
7.1	Chapter 1 . . . . .	219
7.2	Chapter 2 . . . . .	220
7.3	Chapter 4 . . . . .	221
7.3.1	EIM BOX . . . . .	221
7.3.2	EGSE boards power supplies . . . . .	222
7.3.3	UUTs power supplies . . . . .	222
7.3.4	DIN rail . . . . .	222
7.3.5	Laptop . . . . .	224
7.3.6	PPU(Power Protection Unit) . . . . .	224
7.3.7	Power strip . . . . .	225
7.3.8	Rack box . . . . .	225
7.3.9	EGSE cables . . . . .	225

---

7.3.10 NICOMATIC datasheets . . . . .	229
7.3.11 Frontal pannel connectors . . . . .	229

# List of Figures

1.1	Project partner companies . . . . .	1
1.2	Antenna sketch . . . . .	4
1.3	RFCB detail . . . . .	5
1.4	DL line details . . . . .	5
1.5	Rx antenna disposition . . . . .	6
1.6	Tx antenna disposition . . . . .	7
1.7	Gantt diagram of the project . . . . .	10
2.1	Phases, activities and review dates . . . . .	12
2.2	Ranges and duration of qualification tests . . . . .	15
2.3	Ranges and durations of acceptance test . . . . .	16
3.1	Rack examples . . . . .	19
3.2	RFCB_RX case . . . . .	20
3.3	RFCB_TX case . . . . .	21
3.4	RFCB_SC case . . . . .	21
3.5	RFCB_GEO case . . . . .	22
3.6	RFCB_GEO_MONO case . . . . .	22
3.7	5xRFCB_DUMMY case . . . . .	23
3.8	6xRFCB_DUMMY case . . . . .	23

3.9	EM1 case . . . . .	24
3.10	EM2 case . . . . .	24
3.11	EM3 case . . . . .	25
3.12	EM4 case . . . . .	25
3.13	EQM case . . . . .	26
3.14	PFM1 case . . . . .	26
3.15	PFM2 case . . . . .	27
3.16	FM_RX_A case . . . . .	27
3.17	FM_RX_B case . . . . .	28
3.18	FM_RX_C case . . . . .	28
3.19	FM_RX_D case . . . . .	29
3.20	FM_RX_E case . . . . .	29
3.21	FM_RX_F case . . . . .	30
3.22	FM_RX_G case . . . . .	30
3.23	FM_RX_H case . . . . .	31
3.24	RFCB interface detail . . . . .	33
3.25	DL HEAD interface detail . . . . .	35
3.26	DL TAIL DUAL and DL TAIL MONO interface detail . . . . .	37
4.1	EIM BOARD interfaces detail . . . . .	43
4.2	NICOMATIC logo . . . . .	44
4.3	102Y02 connector . . . . .	45
4.4	DB DUMMY interfaces detail . . . . .	46
4.5	DB DUMMY J1 and J2 interfaces detail . . . . .	47
4.6	DB DUMMY J3 and J4 interfaces detail . . . . .	47
4.7	DB DUMMY J5 interfaces detail . . . . .	47
4.8	MCCM DUMMY interfaces detail . . . . .	49
4.9	MCCM DUMMY interposer detail . . . . .	49

4.10	MCCM DUMMY J5 interface detail . . . . .	50
4.11	MCCM DUMMY J6 and J7 interfaces detail . . . . .	50
4.12	MCCM DUMMY J8 interface detail . . . . .	51
4.13	RS Components logo . . . . .	54
4.14	MEANWELL logo . . . . .	56
4.15	MCCM consume . . . . .	58
4.16	EIM BOARD consume . . . . .	59
4.17	RSP series . . . . .	59
4.18	RSP-100 models . . . . .	60
4.19	RSP-150 models . . . . .	60
4.20	HRPG series . . . . .	61
4.21	HRP-100 models . . . . .	61
4.22	HRPG-150 models . . . . .	61
4.23	MSP series . . . . .	62
4.24	MSP-100 models . . . . .	62
4.25	MSP-200 models . . . . .	62
4.26	Solidworks logo . . . . .	63
4.27	EIM BOX plan . . . . .	63
4.28	EIM BOARD placed into the EIM BOX . . . . .	64
4.29	EIM BOX space for the front connectors . . . . .	65
4.30	EIM BOX space for power supplies . . . . .	66
4.31	EIM BOX measures for power supplies . . . . .	67
4.32	HRPG-150-3v3 power supply price . . . . .	69
4.33	HRPG-150-5 power supply price . . . . .	69
4.34	HRPG-150-12 power supply price . . . . .	69
4.35	Power supplies price . . . . .	70
4.36	MCCM consumption . . . . .	71
4.37	Line type 1 consumption . . . . .	72

---

4.38	Line type 2 consumption . . . . .	72
4.39	Line type 3 consumption . . . . .	73
4.40	Line type 4 consumption . . . . .	73
4.41	Line type 5 consumption . . . . .	73
4.42	Line type 6 consumption . . . . .	74
4.43	Line type 7 consumption . . . . .	74
4.44	Line type 8 consumption . . . . .	74
4.45	Maximun consumption per line . . . . .	75
4.46	Keysight Technologies logo . . . . .	75
4.47	Power supplies series . . . . .	76
4.48	Mainframes models . . . . .	77
4.49	Power supplies models . . . . .	78
4.50	N6742B module specifications . . . . .	78
4.51	N6732B module specifications . . . . .	79
4.52	N6733B module specifications . . . . .	80
4.53	Power supplies final price . . . . .	81
4.54	USB-8452 model . . . . .	83
4.55	Space of the EIM BOX for the USB-SPI . . . . .	83
4.56	USB-8452 price . . . . .	84
4.57	USB-6509 model . . . . .	84
4.58	USB-6509 price . . . . .	85
4.59	EDS-205A model . . . . .	86
4.60	EDS-205A price . . . . .	86
4.61	STARTECH logo . . . . .	87
4.62	HUB-USB models . . . . .	88
4.63	HUB-USB price . . . . .	89
4.64	SCHNEIDER ELECTRIC logo . . . . .	89
4.65	Available models on the web site . . . . .	90

---

4.66	ABL8RPS24030 model . . . . .	90
4.67	DIN-CARRIL price . . . . .	92
4.68	Satellite Pro C50-E photo . . . . .	93
4.69	Satellite Pro C50-E price . . . . .	93
4.70	HRPG-150 series efficiency . . . . .	95
4.71	UUTs power supplies efficiency . . . . .	96
4.72	DIN CARRIL power supply efficiency . . . . .	97
4.73	Laptop efficiency . . . . .	98
4.74	Current cut-off curves types . . . . .	99
4.75	A9F92203 model . . . . .	100
4.76	Differential switch classes . . . . .	101
4.77	Differential switch models . . . . .	101
4.78	A9Q21225 model . . . . .	102
4.79	XB4BT842 emergency stop button model . . . . .	102
4.80	Relay models on the website . . . . .	103
4.81	Relay models after filters . . . . .	104
4.82	A9C22712 model . . . . .	104
4.83	2CU3L model . . . . .	105
4.84	2CU3L price . . . . .	105
4.85	DK 7240220 price . . . . .	107
4.86	SMA20024 price . . . . .	108
4.87	EGSE diagram . . . . .	111
4.88	W14 cable . . . . .	113
4.89	W16 cable . . . . .	113
4.90	W17 cable . . . . .	114
4.91	USB front panel connector . . . . .	115
4.92	W19 cable . . . . .	116
4.93	W20 cable . . . . .	116

---

4.94 W21 cable . . . . .	117
4.95 24V power supply datasheet . . . . .	118
4.96 W22 cable . . . . .	118
4.97 W22 seccion . . . . .	118
4.98 AWG table . . . . .	119
4.99 HUB-USB datasheet . . . . .	119
4.100ETHERNET front panel connector . . . . .	121
4.101W26 price . . . . .	122
4.102Draftsight logo . . . . .	123
4.103Nicomatic connector's series . . . . .	124
4.104Conductors prices . . . . .	125
4.105AWG table for wires . . . . .	126
4.106Braided sleeves models . . . . .	128
4.107Labels models . . . . .	128
4.108W01_P2.a. . . . .	130
4.109W01_P2.b. . . . .	131
4.110W01_P2.c. . . . .	131
4.111W01_P2.d. . . . .	132
4.112W01_P2.e. . . . .	132
4.113W01_P2.f. . . . .	133
4.114W01_P1.c. . . . .	134
4.115W01_P1.f. . . . .	134
4.116W01 plan and labels . . . . .	136
4.117Cooper sleeve models . . . . .	138
4.118Cooper sleeve price . . . . .	139
4.11962 pin's connector dimensions . . . . .	140
4.12037W backshell dimensions . . . . .	141
4.12137W backshell price . . . . .	141

---



4.12244 pin's connector dimensions . . . . .	142
4.12325W backshell dimensions . . . . .	142
4.12425W backshell price . . . . .	143
4.12526 pin's connector dimensions . . . . .	144
4.12615W backshell dimensions . . . . .	145
4.12715W backshell price . . . . .	145
4.12878 pin's connector dimensions . . . . .	146
4.12950W backshell dimensions . . . . .	147
4.13050W backshell price . . . . .	147
4.131W03 connector . . . . .	148
4.132W03 breadboard . . . . .	149
4.133W03 female connector . . . . .	150
4.134W03 male connector . . . . .	150
4.135W03 plan . . . . .	151
4.136W03 label . . . . .	151
4.137W05 and W06 connector . . . . .	153
4.138W05/W06 plan . . . . .	154
4.139W05 and W06 label . . . . .	154
4.140W08 P1 connector . . . . .	156
4.141W08 P2 connector . . . . .	157
4.142W08 plan and labels . . . . .	158
4.143W08 Backshell . . . . .	160
4.144W50 P1 connector . . . . .	161
4.145W50 P1 connector price . . . . .	161
4.146W50 P2-P5 connector . . . . .	162
4.147W50 P2-P5 connector price . . . . .	162
4.148W50 Plan . . . . .	163
4.149W50 labels . . . . .	163

4.150W09 J4 connector . . . . .	164
4.151W09 P1 connector . . . . .	165
4.152W09 plan . . . . .	166
4.153W09 labels . . . . .	166
4.154W10 P1 connector . . . . .	167
4.155W10 J1.a. connector . . . . .	167
4.156W10 J1.b. connector . . . . .	168
4.157W10 plan . . . . .	168
4.158W10 labels . . . . .	169
4.159Power supplies connector . . . . .	170
4.160W11 plan . . . . .	171
4.161W11 labels . . . . .	171
4.162W12 P1 connector . . . . .	174
4.163W12 P1 price . . . . .	174
4.164HRPG-150 series datasheet . . . . .	175
4.165CN100 connector price . . . . .	176
4.166CN100 pins price . . . . .	176
4.167Fork terminals . . . . .	177
4.168W12 plan . . . . .	178
4.169W12 labels . . . . .	179
4.170W13 P1 connector . . . . .	180
4.171Front panel voltmeter for W13 . . . . .	181
4.172Eyelet-shaped terminal for W13 . . . . .	181
4.173W13 plan . . . . .	182
4.174W13 labels . . . . .	182
4.175W15 panel connector . . . . .	183
4.176Fork sockets connectors . . . . .	184
4.177Fork terminal . . . . .	184

4.178	W15 plan . . . . .	185
4.179	W15 labels . . . . .	185
4.180	Cable price for W15 . . . . .	186
4.181	J1.c. and J2.c. connector price . . . . .	187
4.182	Fork terminals price . . . . .	188
4.183	Voltmeter panel connector . . . . .	188
4.184	Fuse panel connector . . . . .	189
4.185	W34 plan . . . . .	190
4.186	W34 labels . . . . .	190
4.187	Front panel design . . . . .	192
5.1	EIM BOX plant . . . . .	197
5.2	EGSE boards power supplies connection detail . . . . .	198
5.3	W10, W11 and W34 checking . . . . .	199
5.4	EIM BOX with all the cables . . . . .	200
5.5	EIM BOX close . . . . .	201
5.6	EIM BOX working . . . . .	201
5.7	PPU frontal detail . . . . .	202
5.8	PPU rear view detail . . . . .	203
5.9	PPU rear view detail . . . . .	203
5.10	Rack front view . . . . .	204
5.11	Rack back view . . . . .	205
5.12	Rack working . . . . .	206
5.13	EGSE cables test with boards . . . . .	207
6.1	EGSE mainframe budget . . . . .	209
6.2	COTS cables budget . . . . .	210
6.3	CABLES EXT components price . . . . .	211
6.4	CABLES INT components price . . . . .	212

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6.5	EIM BOX frontal panel components price . . . . .	213
6.6	Total quantity of wire used . . . . .	214
6.7	Total wire price . . . . .	214
6.8	Total quantity of labels used . . . . .	215
6.9	Labels price . . . . .	215
6.10	Total quantity of braided sleeve used . . . . .	216
6.11	Braided sleeve price . . . . .	216
6.12	Total EGSE price . . . . .	217

# Glossary

**Airbus Defence and Space** Airbus Defence and Space is a division of Airbus responsible for defence and aerospace products and services. The division was formed in January 2014 during the corporate restructuring of European Aeronautic Defence and Space (EADS), and comprises the former Airbus Military, Astrium, and Cassidian divisions.[6] It is the world's second largest space company after Boeing and one of the top ten defence companies in the world..

**Altium Designer® 19** EDA software used to design PCB from schematics. It allows 3D Design, as well as electronics simulation.

**Celestia STS** company established in 1985 that provides ground-based solutions in the domains of satellite simulation, testing, communication, and data processing..

**CubeSat** Miniaturized satellite normally for space research, with dimensions of 1 dm<sup>3</sup> and mass lower than 1.33 kg per unit.

**Electrical Ground Support Equipment** are tools used by satellite and sub-system manufacturers and integrators to test and validate electrical functions of the satellite on the ground before launch. EGSE consists of hardware and/or software elements that perform satellite testing, by simulating the interfaces of missing (sub-)systems to assure full compatibility once integrated within the overall platform..

**European Cooperation for Space Standardization** is an initiative established to develop a coherent, single set of user-friendly standards for all European space activities..

**European Space Agency** ESA is an intergovernmental organisation of 19 Member States, established in 1975 with the mission to coordinate the development of European space capabilities and to ensure that investment in the space sector translates into benefits for the citizens of Europe, and the world at large..

**Keysight Technologies** is the world's leading electronic measurement company, transforming today's measurement experience through innovations in wireless, modular, and software solutions..

**PROA** is a software developed inside the company, in order to be able to work with a ticketing and versioning system..

**SAP** is one of the world's leading producers of business process management software, developing solutions that facilitate the efficient processing of data and the flow of information between organisations..

**Solidworks** is the world's leading electronic measurement company, transforming today's measurement experience through innovations in wireless, modular, and software solutions..

**SolidWorks®** CAD Software from Dessault Systèmes for 3D Mechanical Design.

**Tecnobit-Grupo Oesia** is a company based in Valdepeñas, which designs, develops and maintains electronic engineering systems and products for the Security, Defence and Aerospace sectors, as well as for civil society, with the aim of providing services and equipment at the forefront of modernity and technology..

**Thales Alenia Space** Thales Alenia Space in Spain has more than 30 years of experience in the design and delivery of innovative solutions for the space market. Leader in the satellite segment in Spain, it has contributed to more than 600 satellites, probes and spacecraft in telecommunications, navigation, Earth observation and solar system and universe exploration missions for space agencies and satellite operators worldwide..

**Tortoise SVN** TortoiseSVN is a really easy to use Revision control / version control / source control software for Windows. It is based on Apache™ Subversion (SVN)®; TortoiseSVN provides a nice and easy user interface for Subversion. It is developed under the GPL. Which means it is completely free for anyone to use, including in a commercial environment, without any restriction. The source code is also freely available, so you can even develop your own version if you wish to..

# Acronyms

**ADS**<sup>®</sup> Advanced Design System.

**COTS** Commercial Of The Shelf.

**EDA** Electronic Design Automation.

**ESA** European Space Agency.

**GCC** GNU Compiler Collection.

**GUI** Graphical User Interface.

**IDE** Integrated Development Environment.

**MCU** Microcontroller Unit.

**PCB** Printed Circuit Board.

**SDCC** Small Device C Compiler.

**USB** Universal Serial Bus.





# Introduction

The following document presents the Final Project of the Degree in Telecommunication Technologies Engineering at the University of Granada. The objective is to expose the work done by the author in the company [Tecnobit-Grupo Oesia](#) during the 6 months that he has been doing an internship. During his internship, the author collaborated in the design, construction and verification of the radio frequency distribution and control electronics for the Spanish Government and Ministry of Defence's satellites SPAINSAT NG I and SPAINSAT NG II, with the collaboration of major companies in the sector such as the [European Space Agency \(ESA\)](#), [Airbus Defence and Space](#) and [Thales Alenia Space](#).



**Figure 1.1** – Project partner companies

## 1.1 State of the art: Spainsat NG Project

1

In 2005, the Xtar-Eur satellite was launched into space, and in 2006, the SPAINSAT satellite was launched, both geostationary satellites located at the 29°East and 30°West orbital positions respectively. The SPAINSAT satellite is the main satellite, and can operate in the X and Ka bands for use by the Ministry of Defence. The Xtar-Eur satellite, which only has X-band capacity, is the redundant satellite and provides the same coverage as the main satellite in the event of a total failure of the latter. In addition to military use, both satellites are also used for communications by the Spanish government and other allied or friendly governments. These satellites were designed to have a life expectancy of 15 years, that is, until 2020 and 2021, but their life has been extended to 2023 and 2024.

This is where the need arises to replace both satellites with new ones using the latest technology. This is how the SPAINSAT NEW GENERATION (SPAINSAT NG) project was born, which will have two new satellites, SPAINSAT NG I and SPAINSAT NG II. The first is expected to be launched at the end of 2023, to become operational in 2024, and the second will follow in its footsteps 12 months later, in 2025. Both have a life expectancy of 15 years, so they are expected to operate until 2040, and contain significant changes compared to their predecessors. These two satellites, in addition to working in the X and Fa bands, will have the capacity to operate in the military UHF band, placing Spain at the forefront of the few countries in the world with national systems in this band. The development of this project will be a major step forward for the Spanish industry, as it will provide the communications payloads for both satellites. The range of coverage of these satellites will be 2/3 of the planet, covering regions ranging from North and South America, Africa, Europe, and even Asia as far as Singapore, and they will have the latest technologies to prevent intrusion, interference or identity theft in communications, as well as being protected against nuclear phenomena at high altitude. The satellites will have active antennas with in-orbit reconfiguration capabilities, allowing electronic reorientation of the coverage beams.

The development of the satellites is supported by the Ministry of Industry, Tourism and Trade and the Centre for the Development of Industrial Technology (CDTI), based on a public-private agreement between the [European Space Agency](#) (ESA) and the satellite operator, Hisdesat. The latter company is the owner and operator of the satellites, and selected [Airbus Defence and Space](#) companies in Spain and France, and [Thales Alenia Space](#) in both countries, to build the satellite. Several Spanish companies in the sector will be responsible for providing the communications payloads for both satellites, and this is where [Tecnobit-Grupo Oesia](#) comes in, which is the company that will be in charge of supplying the distribution electronics and radio frequency control for the antennas of both satellites.

## 1.2 Motivation

### 1.2.1 Personal motivation

Since the beginning of the academic year, I had been trying to find a topic that I thought would be interesting for my Final Year Project, I looked at the topics offered and, although there were several that made me curious and made me want to choose it, I didn't feel that they were exactly what I was looking for. In October, wanting to decide as soon as possible my TFG topic, I found in an email from the University three internship offers in different companies, two in Granada, my city, and one in Valdepeñas, Ciudad Real. Although all the offers were good options and in two of them, I had the possibility of staying in my city, as soon as I saw the opportunity and the project that [Tecnobit-Grupo Oesia](#) was offering me, I didn't hesitate at all. I took everything I had, and within a month I was living in Valdepeñas and developing a project that really excited me.

The aerospace sector is a totally innovative sector in which we always work with the latest technologies, which means that I am learning a little more every day, and I am excited to be able to develop my working life in this field. Through this Final Degree Project, I will try to expose all the knowledge learned in these fantastic 6 months in the company, the different difficulties and decisions that we have encountered along the way and how we have managed to overcome them to build the test equipment necessary to verify the supply of distribution electronics and radio frequency control of the antennas.

### 1.2.2 Project motivation

On the battlefield, there is no doubt that communications are a critical factor in determining the chances of victory. Communications help you gather information on the position of allies or enemies, as well as monitor the various variables that could alter a conflict. Over time, communications systems have become more sophisticated and technologically advanced. Nowadays, and with the joint work of so many armies from different countries, the areas of action will never be fixed, which will mean that communications will have to be maintained in different points of the planet far apart and, because of this, the need to develop a satellite capable of changing its radiation zones to maintain good communication at all times. In addition, having our own satellites is always an advantage in the event of conflict, as we would be relying on ourselves and not on foreign governments.

This is where the motivation for the project to create a Spanish satellite capable of meeting the maximum demands that may arise during a conflict comes from. For this reason, Spanish industry has been mainly involved in the manufacture of the aforementioned satellite, and [Tecnobit-Grupo Oesia](#) in the development of the distribution electronics and the radio frequency control of the antennas. This project will open up the space sector in the company and will represent a major step forward in its position compared to other companies in the sector.

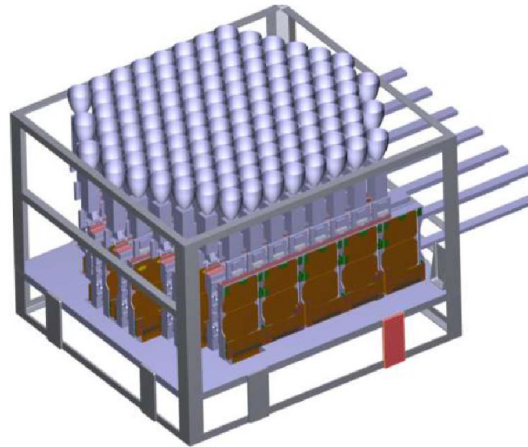
### 1.3 Objectives

1

As mentioned above, the company will develop the distribution electronics and the radio frequency control of the antennas. [Tecnobit-Grupo Oesia](#) is a company contracted by the [Airbus Defence and Space](#) division in Spain, and will therefore be in charge of developing the product with the help of the latter.

The electronic distribution is the set of PCBs and EEE components that are close to the radiating elements, distributing power, control and monitoring signals from the elements. Active antennas are divided into two groups of electronics, Transmission Electronics (TX) and Reception Electronics (RX).

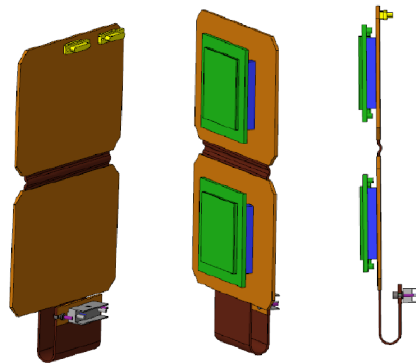
In the following, it will be shown the basic concepts to know in order to understand the work done.



**Figure 1.2** – *Antenna sketch*

In the figure above we can see an example of a receiving or transmitting antenna, and we can see how the electronics associated with it (lower part in brown) is divided into parallel lines and columns with different numbers of elements each.

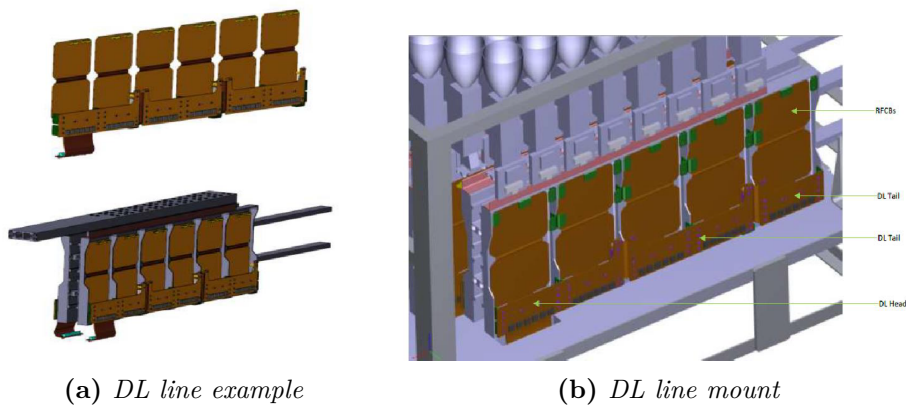
The central element in charge of controlling the radiating elements is called the Multi-chip control Module (MCCM). These MCCMs are mounted on PCBs called RF Control Boards (RFCB). The minimum PCB assembly where the MCCMs are mounted is the Dual RFCB, which contains two MCCMs and consists of a Rigid-flex-Rigid-flex PCB, the rigid part of which is called RFCB and mounts an MCCM.



**Figure 1.3** – *RFCB detail*

In order to distribute the power and control signals through all the RFCBs, PCBs are used, which are placed in parallel and are called Distribution Line (DL).

The first of these PCBs is called DL HEAD, and the adjacent PCBs are called DL TAIL. The DL HEAD always connects two Dual RFCBs, while the DL TAIL can be DL TAIL DUAL if it connects two RFCBs, or DL TAIL MONO if it connects only one RFCB.



(a) *DL line example*

(b) *DL line mount*

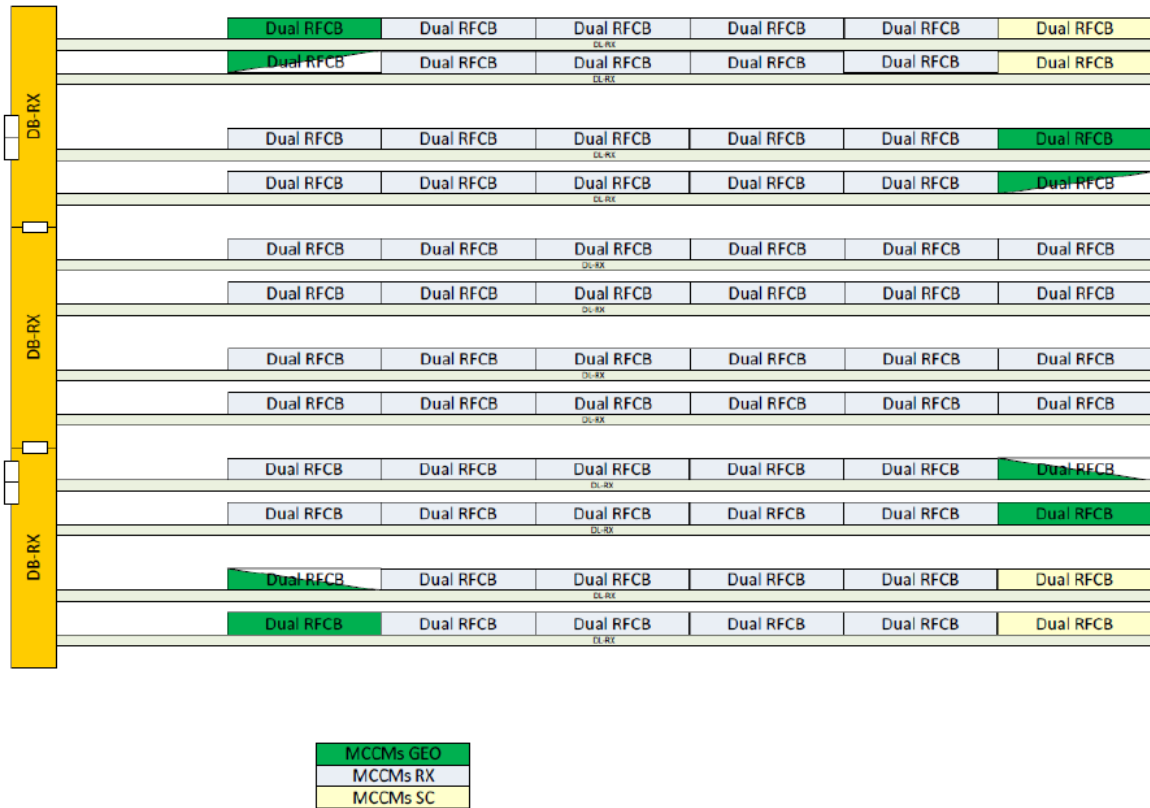
**Figure 1.4** – *DL line details*

The connection between the RFCBs and the DLs will be made via signal connectors that are capable of withstanding high levels of vibration and shock in the harshest environments in space and air, which are manufactured by Smith interconnect and correspond to the MHD series.

The distribution of the different PCBS along the satellite is shown in the following pictures:

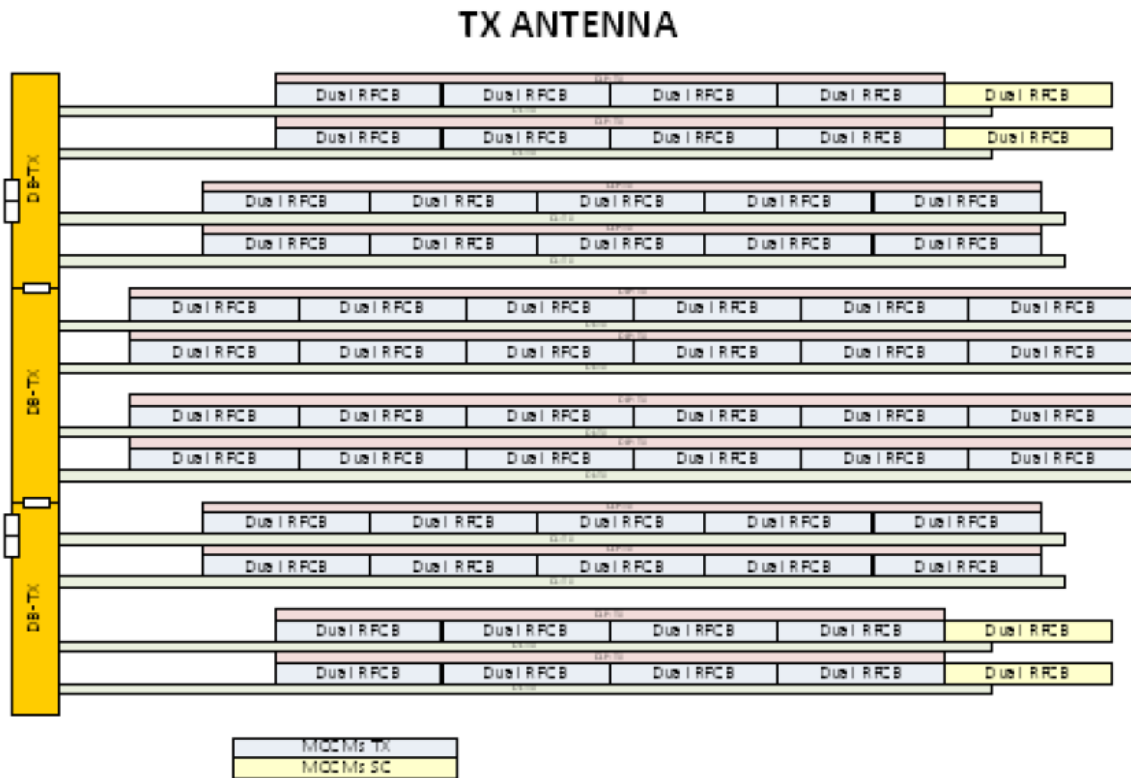
1

### RX ANTENNA



**Figure 1.5** – *Rx antenna disposition*

In the image above it is possible to see the distribution of the different boards that make up the receiving antenna, and we can see that it will be formed by 12 lines of boards, 6 lines of the RIGHT type and another 6 of the MIRROR type; and each of these lines will be formed by 6 Dual RFCBs, so there will also be 3 DLs (1 of the DL HEAD type and 2 of the DL TAIL DUAL type) for each of the lines.



1

Figure 1.6 – Tx antenna disposition

In this other image, however, we see the layout of the boards in the transmission antenna, which has 4 lines of 6 RFCBs each one, 2 RIGHT lines and 2 MIRROR lines with 3 DL boards each one with the same distribution as in the RX ANTENNA; and it also has 8 lines of 5 RFCBs each, 4 RIGHT lines and 4 MIRROR lines, whose distribution of the DLs is going to be different from the ones we have seen so far, since they have a DL HEAD, then a DL TAIL DUAL, and finally a DL TAIL MONO.

The company will develop the RFCBs and DLs necessary for the operation of the satellite. In order to be able to develop them correctly, different interfaces and test boards will be provided by [Airbus Defence and Space](#) or manufactured by the company. It should be made clear that the work carried out by the RFCBs and DLs, distributing the signals and power from the electronic units to the MCCMs, could be done by means of a cable, but the use of PCBs implies that the signals can arrive with greater integrity through the use of buffers, or that the elements are more robust and compact to withstand the different circumstances that may be encountered in space or at launch.

## 1.4 Methodology

1

The methodology to be followed for the development of the project will be as follows:

- **System requirements.** Final requirements agreed with Airbus for the project, both hardware requirements (working temperature, durability, resistance, ...) and software requirements.
- **Analysis and design.** Having the necessary requirements, analysis and assessment of the different options available on the market, and selection of one of the alternatives for the design of the equipment.
- **Implementation.** Reception of the necessary parts for the assembly of the test equipment, and step-by-step construction of the equipment.
- **Testing and verification of the system.** Once all the equipment has been assembled, the tests carried out and the different results obtained to check that it complies with the proposed requirements.

Throughout the development, we will work through a versioning process, in which we will use programmes such as [SAP](#), the world leader in business management software; [PROA](#), software created in Tecnobit-Grupo Oesia for the verification and version control process, and [Tortoise SVN](#), for the management of development and software documents.



(a) *SAP logo*



(b) *Tortoise SVN logo*



## 1.5 Project Structure

The Final Degree Project has seven chapters in which, within the development of each one, the general information of the project will be shown, and the part corresponding to that carried out by the author within the company will be specified. The chapters are as follows:

- **Introduction.** The context and organisation of the Final Degree Project and the associated project will be explained, the motivation of this document will be explained, and the reader will be introduced to the understanding of this document.
- **Space Systems.** The methodology to be followed during the development of a space system of the European Space Agency will be explained, focusing on the stage developed within the company.
- **System Requirements.** The requirements agreed with Airbus or the participating companies for the correct functioning of the system will be explained, which can be mechanical, software, hardware or operational requirements.
- **System Analysis and Design.** The different possibilities to be chosen during the analysis process, the choices made for the design and some of the software used will be shown. In this part I will focus mainly on the mechanical and hardware parts, which are the ones I have become more familiar with during my internship in the company.
- **Implementation.** The final result of the test equipment will be shown with photos.
- **Project Budget.** Estimation of the costs associated with the project and explanation of the cost of some of the components.
- **Conclusion.** Evaluation of the work carried out and forecast of what the project can contribute.

## 1.6 Time management

A success project does not only rely on the the final product and results, but also on the development process. Two essential facts that must be taken into consideration during this process are tasks identification and time management. Indeed, drafting a realistic working schedule at the commence of the project might influence the rest. For that purpose, a Gantt Chart has been prepared.

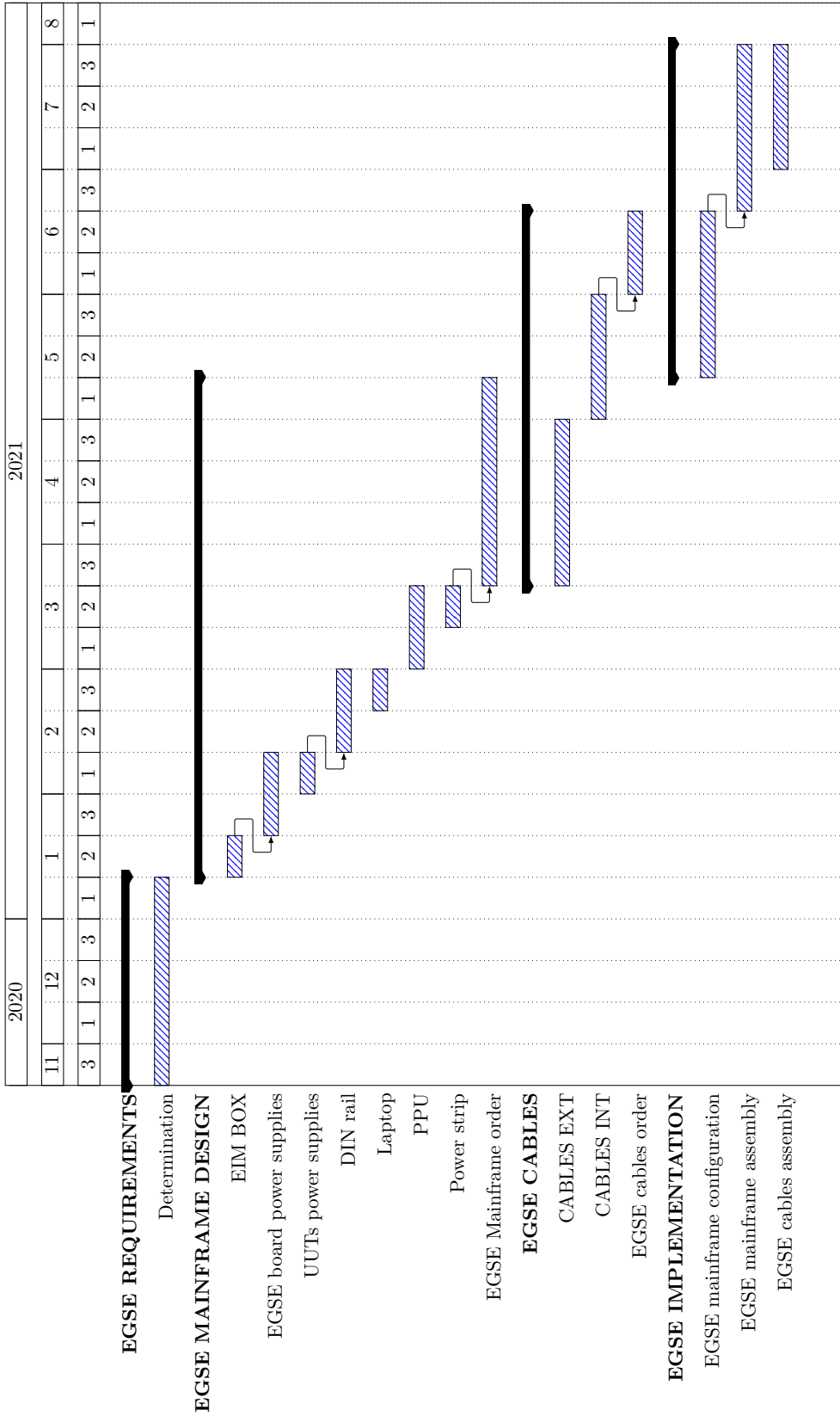


Figure 1.7 – Gantt diagram of the project

# Space Systems

During its life in space, any system will have to operate in working conditions that do not exist on our planet, such as temperature ranges, pressure, cosmic radiation, micrometeorites, etc. These conditions, together with the fact that any system once in space cannot be modified, mean that the components and materials used in these systems must be more expensive than those we are used to, in order to ensure a high degree of reliability and performance. Logically, the cost of these materials does not allow for continuous work with them, since due to the possible problems that could be encountered during the development of the system, the budget associated with the project would rise rapidly. For this reason, in order to optimise costs and time, space projects follow a working method established in the **ECSS-M-ST-10C** document of the [European Cooperation for Space Standardization](#) (ECSS) in which, depending on the phase of the project, we must work with certain types of materials or others. Starting with [COTS](#) (Commercial off-the-shelf) materials and ending with the materials that will finally travel to space, thus obtaining maximum efficiency of the time and money invested. The different phases indicated in the above-mentioned document, are the following ones:

- **Phase 0.** Mission analysis/needs identification
- **Phase A.** Feasibility
- **Phase B.** Preliminary definition
- **Phase C.** Detailed definition
- **Phase D.** Qualification and production
- **Phase E.** Operations/utilization
- **Phase F.** Disposal

Each phase has at least one review date associated with it, which will make it possible to monitor the status of the activities corresponding to each phase and to evaluate the development of the project. The relationship between the phases, activities and their review dates in this methodology is shown below:

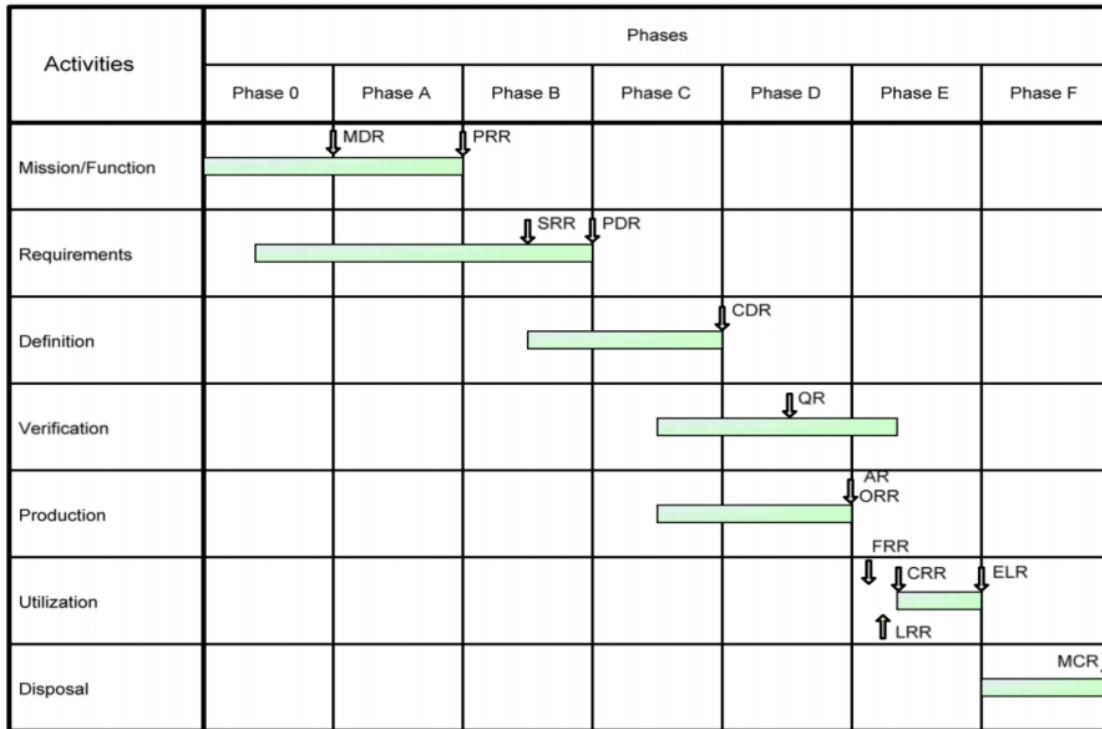


Figure 2.1 – Phases, activities and review dates

It is necessary to clarify that during the development of a project, this path does not have to be strictly followed, but a similar structure does. Now, each of the phases of this work method will be summarised, focusing on **phase C**, in the section on the definition between the dates of **PDR** and **CDR**, since this interval was the one that was worked on during the author’s stay in the company.

## 2.1 Phase 0: Mission analysis/Needs identification

In the first phase of this model, work will be done to identify the needs that the project will have, the scientific barriers that will be encountered, the first technical requirements that will have to be faced or the planning of costs and schedule. This phase ends after the **Mission Definition Review (MDR)**, in which the overall mission concept will be defined.

## 2.2 Phase A: Feasibility

This is where the first technical designs are made and their feasibility and risks are assessed along with possible limitations. It ends with the **Preliminary Requirements Review (PRR)**, where the requirements to be taken into account in the system design are specified.

## 2.3 Phase B: Preliminary definition

Further specification of the system begins, hardware models are decided upon, the schedule and costs are defined, and the chosen solutions are assessed, while design development begins. This phase has two key dates, the **System Requirements Review (SRR)**, which establishes the characteristics of the system based on the technical requirements previously established, and the **Preliminary Design Review (PDR)**, which defines the characteristics of the system based on the technical requirements and design constraints as well as its verification conditions.

## 2.4 Phase C: Detailed definition

During this phase, the detailed design of the system is completed at all levels, and the production and development of the critical elements and components begins, along with the various models needed to verify the system. The key date associated with this phase is the **Critical Design Review (CDR)**, which will be aimed at launching the final design, assembly, integration, test plans and user manual. In this phase, different hardware models will be used depending on how closed the system design is, these models can be the following according to the ESA:

- **MU** : Mock-up model
- **DM** : Development model
- **SM** : Structural model
- **ThM** : Thermal model
- **STM** : Structural-Thermal model
- **Suitcase model**
- **EFM** : Electrical and Functional model
- **EM** : Engineering Model
- **EQM** : Engineering Qualification model
- **QM** : Qualification model
- **LTM** : Life Test model
- **PFM** : Proto-Flight Model

- **FM** : Flight Model
- **FS** : Flight Spare

Although there are many different models with different objectives, we will focus on the models used during project development within the company, which are the EM, EQM, PFM and FM.

## 2

- **EM:** The engineering model is similar to the flight model, as it has the same dimensions and similar functionalities, although not total, but it differs from the flight model in that its components are not as reliable, and therefore cheaper. This model is mainly used to test basic functionalities and for final validations.
- **EQM:** The engineering qualification model is very similar to the previous one, with the small difference that this one fulfils all the functionalities that the system must have and includes military components, which, although they are not flight components, fulfil many of the necessary conditions, but at a much lower price. This model will undergo several qualification tests to verify that the model can withstand the conditions indicated.
- **PFM:** The Proto-Flight model is almost identical to the flight model in that it includes space-ready components and fulfils all the system's functionalities. This model is used to verify that the system will be able to pass the qualification tests, stressing the system as much as possible to check that it is still useful.
- **FM:** The flight model is the final product, it includes all the functionalities and components with which the system was designed, and it will be the model that goes into space. For this reason, this model will only undergo acceptance tests, which will not be so stressful and will allow the components to function normally, once the tests have been completed.

As a practical example, two components of the EM and PFM models are taken. Both are placed in the same position in the models and perform the same functions without stressing them. The difference is that, under high levels of stress, the PFM model will continue to work under high performance, and the EM model will not.

These models will have to be tested under different conditions of temperature, pressure, vibration, etc. These will stress the components of each of the models to a greater or lesser level. Depending on the purpose, duration, or conditions of the tests we want to perform on the system, these can be divided into the following groups:

- **Qualification Tests:** These tests seek to demonstrate that the design and implementation of the hardware and software is correct and that the system has a much larger working range than expected. In order to verify this, the model is subjected to conditions that exceed the range in which it will work in space in order

to ensure that there will be no future problems. These tests are not applicable to flight models because under these tests the model is subjected to high stress conditions that can cause system failures, and therefore the correct functioning of the system cannot be ensured.

- **Acceptance Tests:** These tests must be performed with the objective of demonstrating that the system can be sent to space without altering its functionality, so the tests included in this section must not exceed the conditions and tolerances that the system will encounter in space. Tests should be performed on all flight models, except protoflight models, and should be performed after the qualification programme has been completed.
- **Protoflight Tests:** These are both qualification and acceptance tests performed on the first flight model to verify that it can operate under the conditions of the qualification tests, and to ensure that after this, it can continue to meet the requirements of the acceptance tests.

The differences in both the working ranges and the duration of the tests can be seen in the following tables:

Test	Levels		Duration	
	Equipment	Space element	Equipment	Space element
Shock	+6 dB <sup>a</sup>	N/A	3 shocks in both directions of 3 axes	3 activations of explosive firing
Acoustic	+4 dB <sup>a</sup>	+3 dB	2 min <sup>b</sup>	2 min <sup>b</sup>
Vibration	Random/Sine: +4 dB	Random/Sine: +3 dB	Random: 2,5 min per axis <sup>b</sup> Sine: 2 octave/min 1 sweep up and down (5 Hz-100 Hz)	Random: 2 min per axis <sup>b</sup> Sine: 2 octave/min (5 Hz-100 Hz) (notching, if necessary)
Thermal cycling	10 °C extension of maximum and minimum predicted temperatures <sup>a</sup>	10 °C extension of maximum and minimum predicted temperatures <sup>c</sup>	8 cycles	8 cycles
Thermal vacuum	10 °C extension of maximum and minimum predicted temperatures <sup>a</sup>	10 °C extension of maximum and minimum predicted temperatures <sup>c</sup>	8 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed	8 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed
EMC	+6 dB EMC safety margin		depending on operating modes	
Static/acceleration	1,25	1,25	100 s + 50 s per mission	Sufficient to record test data
Pressure	1,5 (proof), 2 (burst)	1,5	5 min (3 cycles for valves) only for proof	5 min (3 cycles)
Life	N/A (margins only for accelerated tests)		4 times operating life	

Figure 2.2 – Ranges and duration of qualification tests

Test	Levels		Duration	
	Equipment	Space element	Equipment	Space element
Shock	Maximum expected shock spectrum	N/A	1 shock in both directions of 3 axes + dwell and burst tests	1 activation of explosive firing
Acoustic	Envelope of maximum expected acoustic spectrum		2 min	1 min
Vibration	Random: Envelope of maximum and minimum expected spectrum <sup>a</sup>	Random: Envelope of maximum and minimum expected spectrum <sup>a</sup>	Random: 2 min per axis	Random: 1 min per axis
Thermal cycling	5 °C extension of maximum and minimum predicted temperatures <sup>b</sup>	Flight temperature <sup>c</sup>	4 cycles	4 cycles
Thermal vacuum	5 °C extension of maximum and minimum predicted temperatures <sup>b</sup>	Flight temperature <sup>c</sup>	4 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed	4 cycles if combined with thermal cycling, 1 cycle if thermal cycling is performed
Pressure	1,5	1	5 min (only one cycle)	Sufficient to establish leakage

Figure 2.3 – Ranges and durations of acceptance test

## 2.5 Phase D: Qualification and production

This phase corresponds to the end of system development and is where qualification testing is completed and both space and ground systems are checked to ensure that they work equally and meet the agreed requirements and margins. During this phase, there are three key dates: the **Qualification Review (QR)**, which serves to demonstrate that the final design meets all requirements and that verification has been completed; the **Acceptance Review (AR)**, which aims to confirm that there is no human intervention in the final product to avoid any human error and includes the acceptance report; and the **Operational Readiness Review**, which aims to verify that the procedures are compatible for both the flight and ground systems.

## 2.6 Phase E: Operations/Utilization

This phase will depend on the type of project to which it applies, but in general, its objectives are related to the launch, such as performing orbital operations, support activities for the ground and space teams and verifying the correct functioning of both systems. This phase has four key dates such as the **Flight Readiness Review (FRR)**, which serves to verify that the ground and flight equipment, and all communication and tracking systems, are ready for launch; the **Launch Readiness Review (LRR)**, whose objective is to verify that the rocket is ready to be launched and to proceed to its authorisation; the **Commissioning**



**Result Review (CRR)**, where in-orbit tests are performed to verify that all systems are working as expected; and the **End of Life Review (ELR)**, which ensures that all in-orbit elements are configured to maintain safe operation.

## 2.7 Phase F: Disposal

This phase serves to ensure that all activities have been carried out correctly through a final **Mission Close-out Review (MCR)**.

**2**

**2**

## EGSE Requirements

Due to the complexity and work involved in designing and building a space system such as a satellite, as mentioned in previous chapters, it will be divided into different parts that will be designed and manufactured by different companies. For this purpose, the overall system is divided into several subsystems that must comply with the requirements that have been agreed upon, so that, when all of them are put together, the correct functioning of the system is ensured.

In order to ensure that the subsystem meets the requirements, and to verify that it is functioning correctly, an [Electrical Ground Support Equipment](#) (EGSE) is used, which is a device that simulates the different electrical functions of the satellite before launch.

These equipment are usually racks divided into different segments that assume different functions. There are different companies that are responsible for commercialising the different components of the rack, and there are even some companies such as [Celestia STS](#) or [Keysight Technologies](#) that directly commercialise these complete pieces of equipment, as we can see in the following images:



**Figure 3.1** – *Rack examples*

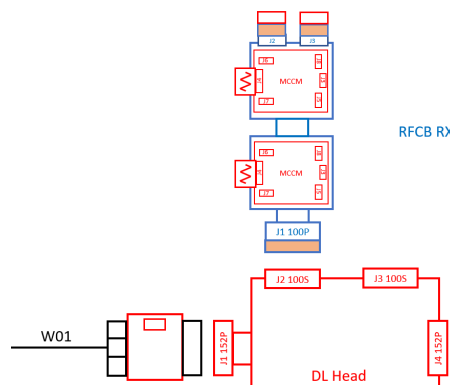
(a) *Celestia STS logo*(b) *Keysight technologies logo*

Although there are good options on the market for equipment that functions as an EGSE, the project will work with an EGSE designed entirely within the company and which will be made up of elements of its own design and manufacture, and commercial elements purchased from other companies. This EGSE can be divided into two large groups, the **EGSE\_MAINFRAME**, which will correspond to the entire Rack and the equipment necessary for the control of the tests; and the **Unit Under Test (UUT)**, which will be the units to be tested. In the same way, in order to establish connections between the EGSE components, different cable units will be used, which may be purchased from other companies or designed and manufactured within the company. These cables can also be classified in **CABLES\_EXT**, if they are in the UUT section, or **CABLES\_INT**, if they are in the EGSE\_MAINFRAME group. In order to establish a connection between the EGSE\_MAINFRAME and the UUT, we will use an internally designed and manufactured cable named **W01\_EXT**, which will be discussed later.

### 3.1 Use cases

The objective of the EGSE designed in-house is to be able to verify the different boards manufactured by the company, in order to check their adaptation to the rest of the satellite system. For this, the EGSE will need to be able to test each of the configurations of the power distribution and signal transmission lines agreed in the requirements with [Airbus Defence and Space](#) (ADS), which are as follows:

- **RFCB\_RX**



**Figure 3.2** – *RFCB\_RX case*

- RFCB\_TX

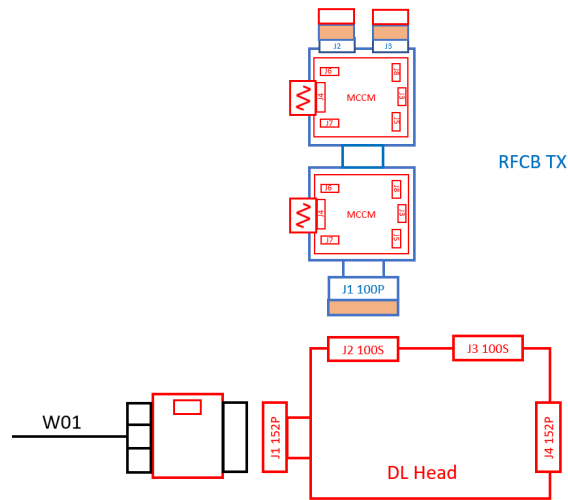


Figure 3.3 – RFCB\_TX case

- RFCB\_SC

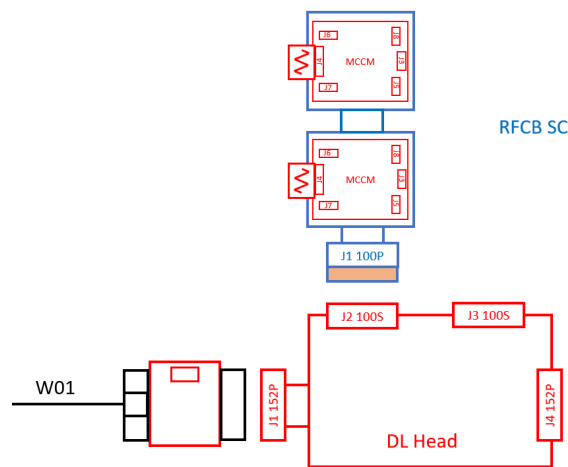


Figure 3.4 – RFCB\_SC case

3





The following cases will be needed for the Engineering Models:

- EM1

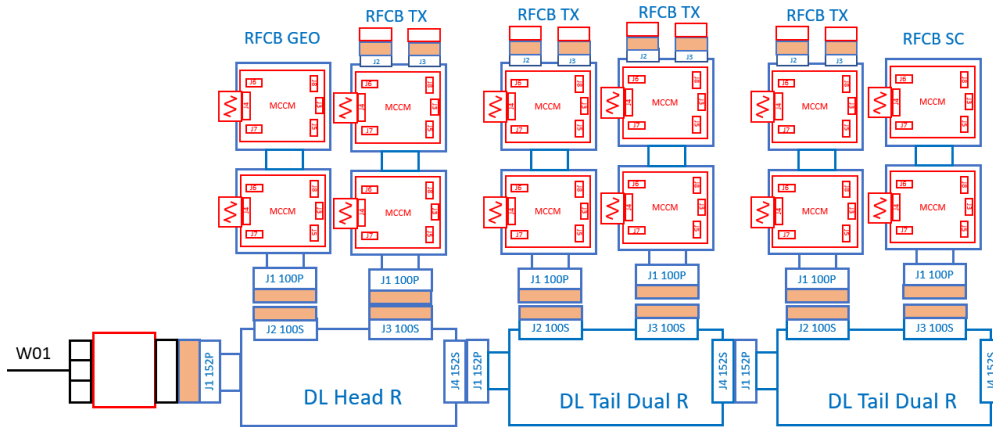


Figure 3.9 – EM1 case

- EM2

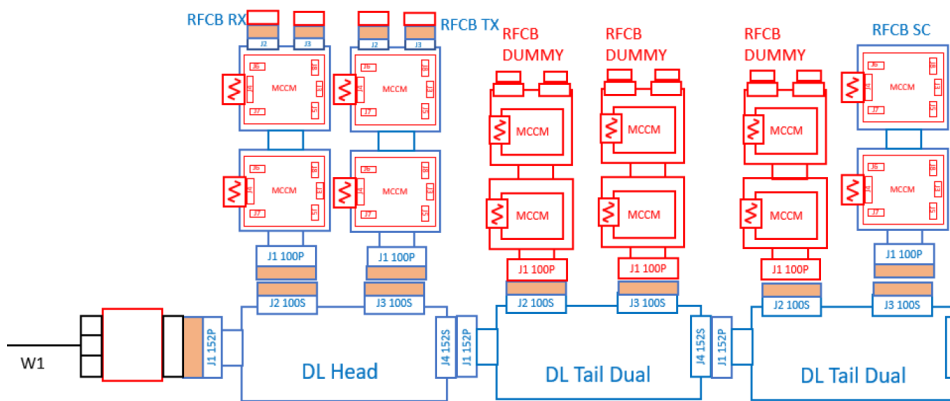


Figure 3.10 – EM2 case



- EM3

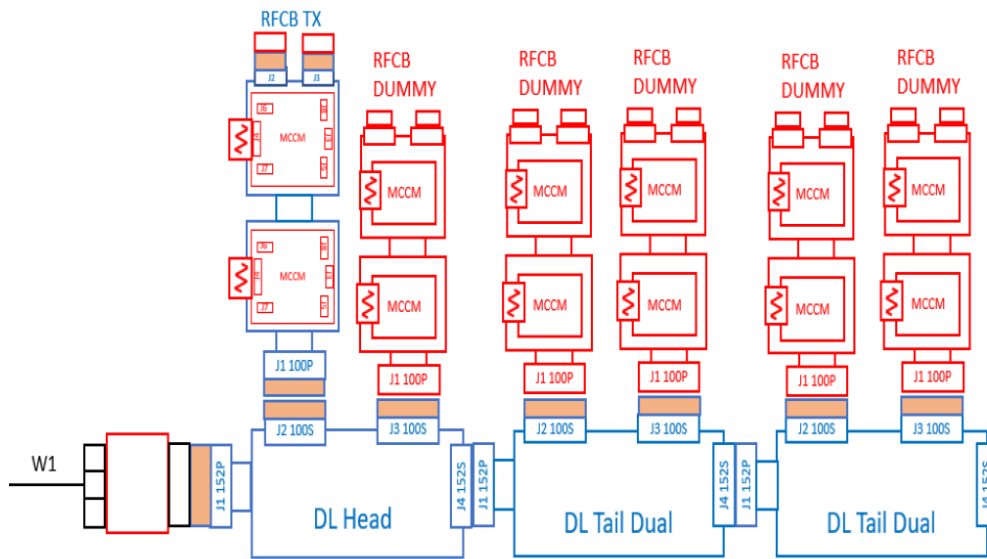


Figure 3.11 – EM3 case

- EM4

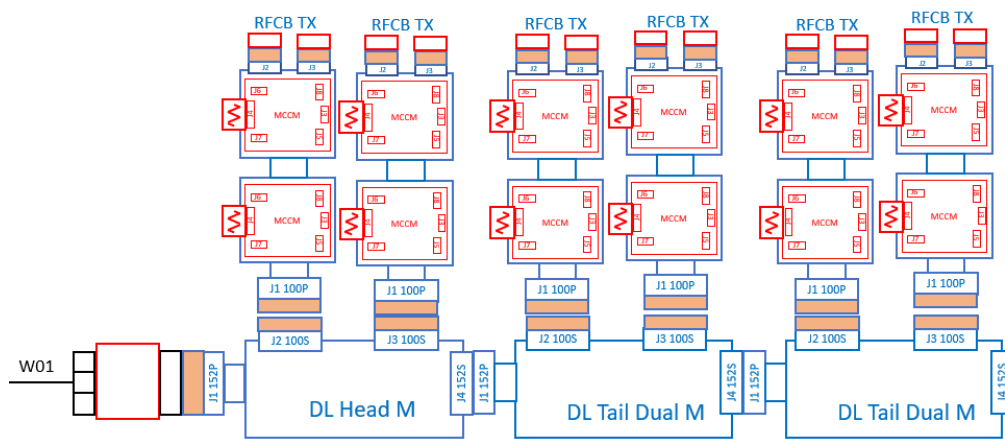


Figure 3.12 – EM4 case

For the qualification models, an EQM case will be defined, which can be tested in a thermal vacuum chamber, using for this purpose two cables that will be attached to the W01 and will be used only for these cases, namely W60\_EXT\_TVAC and W61\_INT\_TVAC.

- EQM

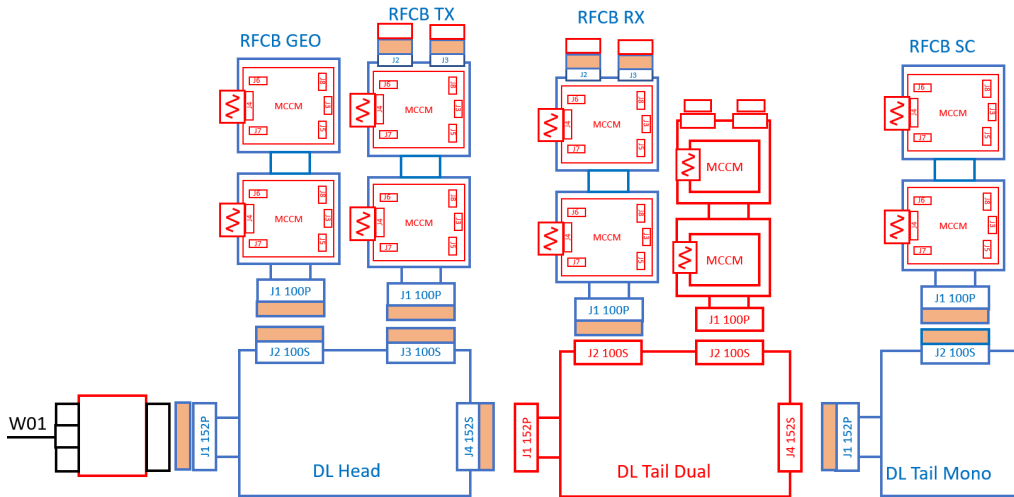


Figure 3.13 – EQM case

For the proto-flight models, two cases will be defined, PFM1 and PFM2, which can also be tested in a thermal vacuum chamber:

- PFM1

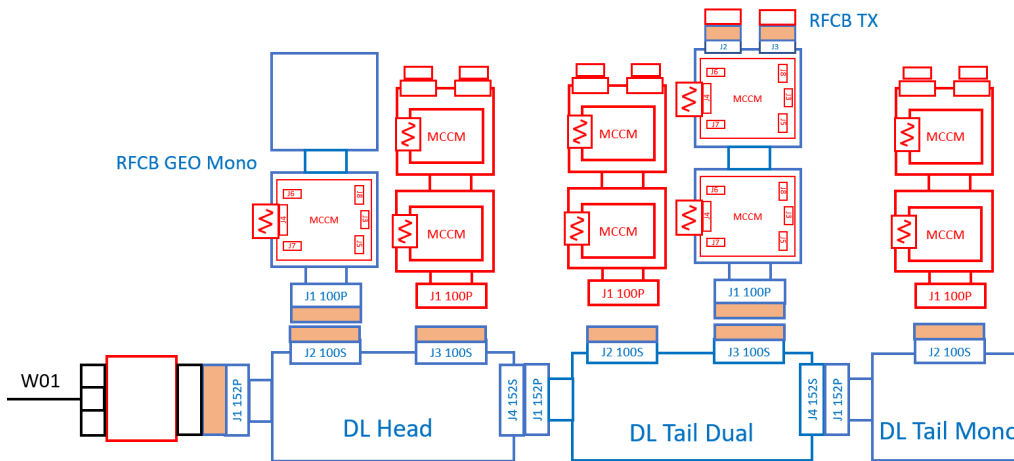


Figure 3.14 – PFM1 case



- FM\_RX\_B

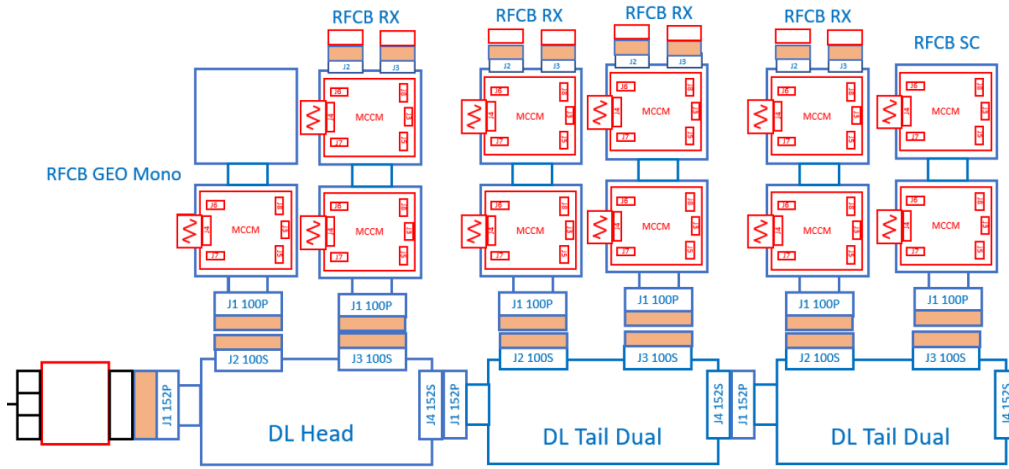


Figure 3.17 – FM\_RX\_B case

- FM\_RX\_C

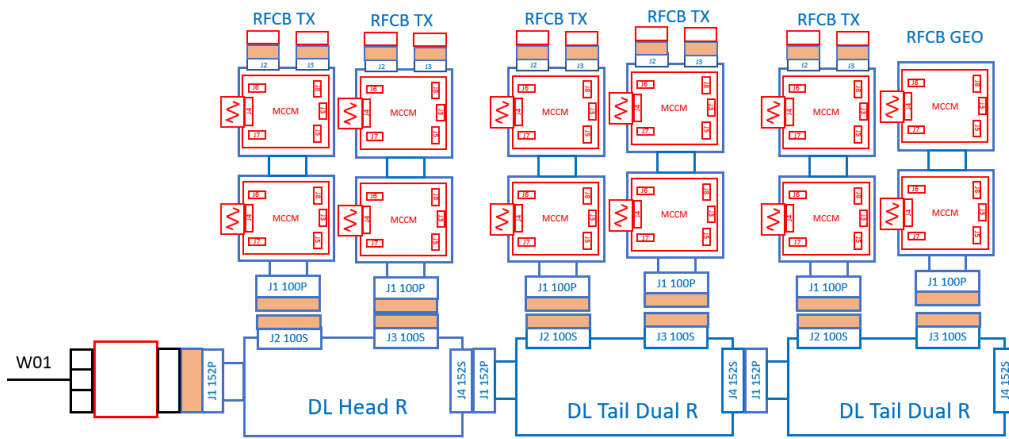


Figure 3.18 – FM\_RX\_C case

3

- FM\_RX\_D

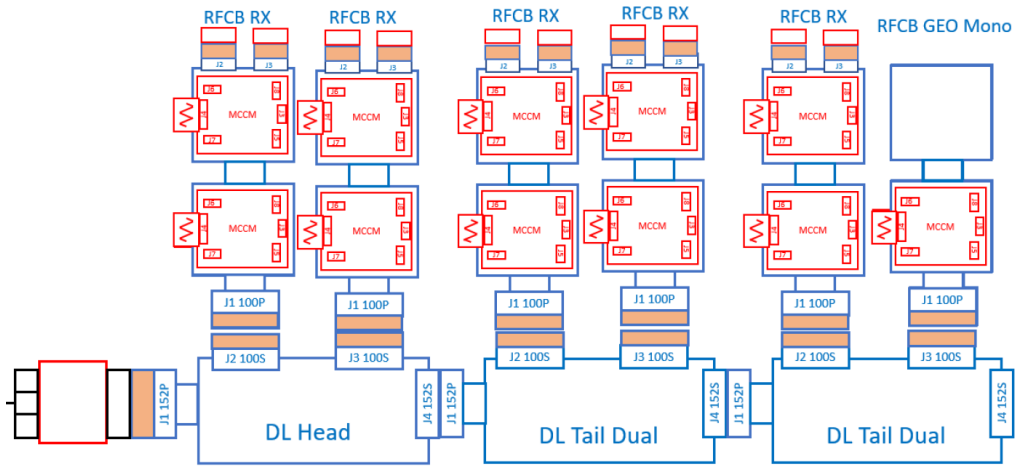


Figure 3.19 – FM\_RX\_D case

- FM\_RX\_E

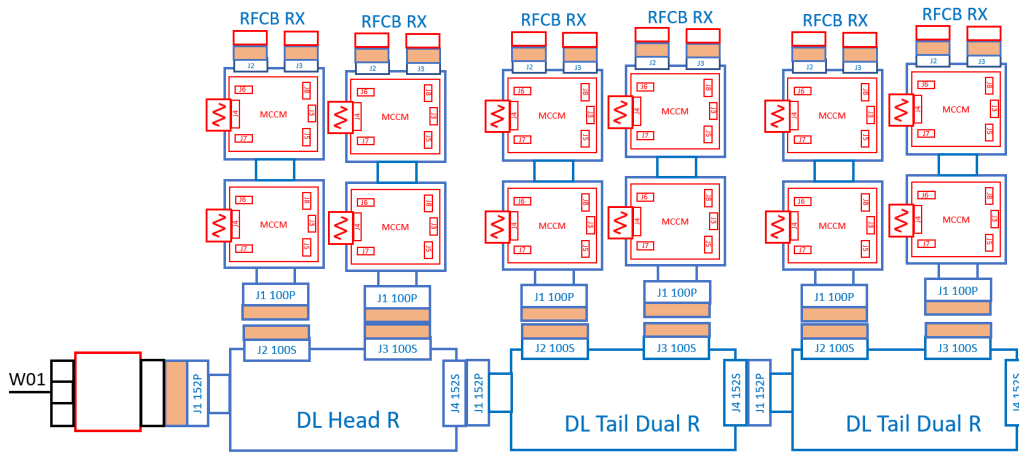


Figure 3.20 – FM\_RX\_E case



- FM\_RX\_F

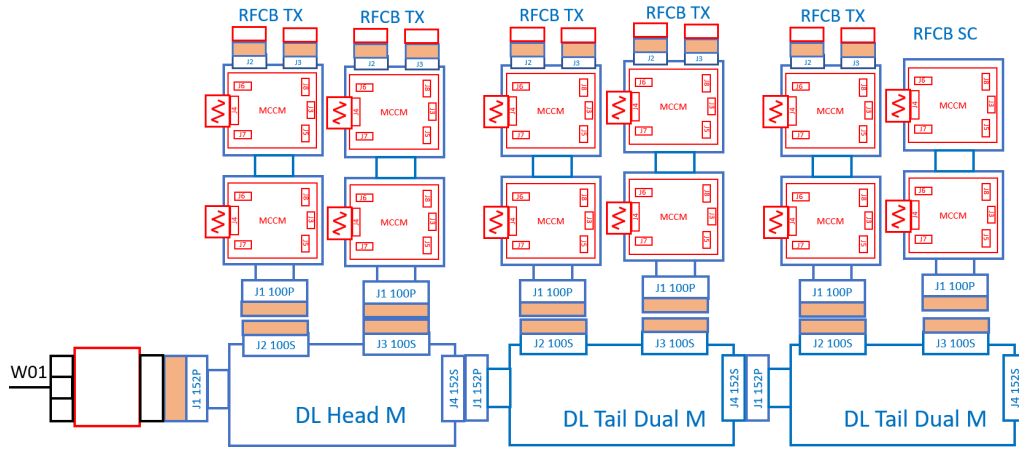


Figure 3.21 – FM\_RX\_F case

- FM\_RX\_G

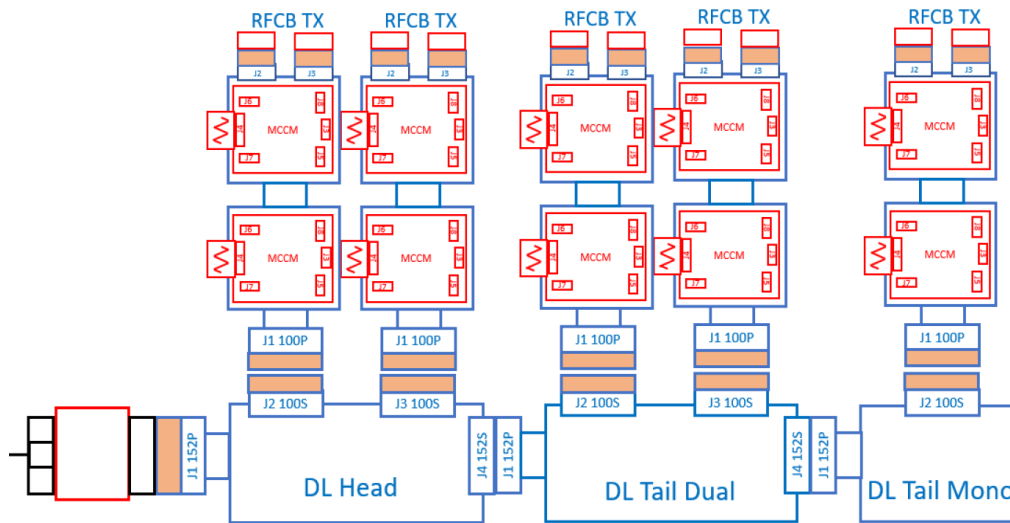


Figure 3.22 – FM\_RX\_G case

3

- **FM\_RX\_H**

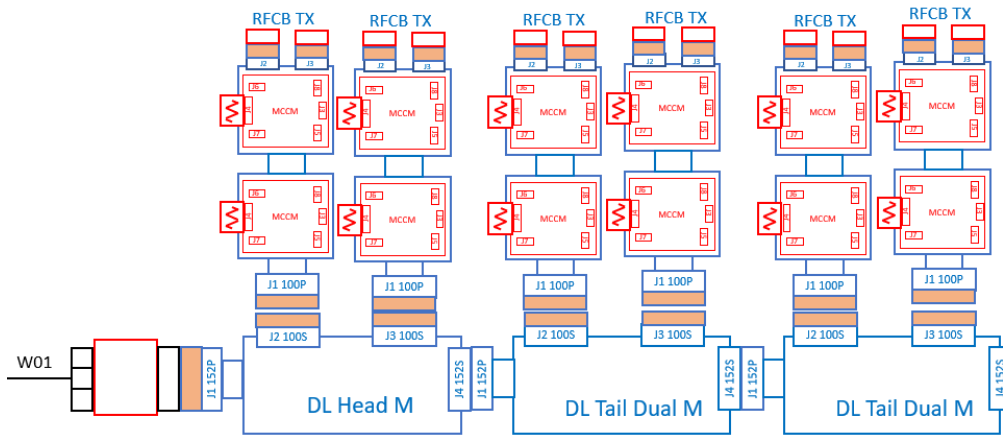


Figure 3.23 – FM\_RX\_H case

### 3.2 Requirements for the functions and performance of the system

The resources to be used for testing should be selected from commercially available items, ideally from different suppliers, and the measurement equipment and sources used should be identified with the model, serial number, calibration and expiry date, and should be standardised at national and/or international level. For the correct functioning of the system, the EGSE must be able to evaluate each RFCB and DL individually, and to have the capability of test all UUT functional blocks.

#### 3.2.1 EGSE BOARDS

These boards will be the ones designed at the company, but they are not deliverable, they will be used only for testing. In the cases of the DB DUMMY BOARD and the MCCM DUMMY BOARD they are test boards that must simulate the real boards manufactured by ADS.

- **EIM BOARD**

The EIM BOARD must be able to establish SPI communications ranging from 500 KHz to 1 MHz with each of the MCCM DUMMYs boards. It must be able to drive the SPI bus for the indicated MCCM of each test, and check that the response corresponds to the chosen MCCM. This board must also be able to generate 5MHz beam hopping signals and the nDBUFF, nDBUFF\_SC, nACT and RESET signals.

- **DB DUMMY BOARD**

This test board must be able to distribute all signals and power from the

EGSE\_MAINFRAME to the DL HEAD BOARD, and must have a connector that matches the J1 connector on the DL HEAD BOARD.

- **MCCM DUMMY BOARD**

These boards must have the ability to measure the six different power voltages inside the MCCM DUMMY (VDD\_MCCM, VDD\_SC, VCC2, VSS, VG\_SSPA, VDD\_LNA), must be able to measure the SPI signals inside the board between the frequencies indicated above, and must be able to measure all the control signals inside the board. In addition, these boards must emulate all the internal loads that are present in the MCCM, and must be able to connect to the RFCBs connection interface.

### 3.2.2 SPAINSAT NG BOARDS

- **RFCB**

The EGSE must be able to test the RFCBs individually, meaning even if the other RFCBs are not connected, and must be able to perform the tests for each of the different use cases listed above (RFCB\_RX, RFCB\_TX, RFCB\_SC, RFCB\_GEO).

- **DL**

They shall be responsible for routing the signals from the DB to each of the RFCBs and the following DLs. The EGSE shall be able to perform the tests for the use cases described above for the DL HEAD, DL HEAD MIRROR, DL TAIL, DL TAIL MIRROR, DL TAIL MONO and DL TAIL MONO MIRROR.

### 3.2.3 EGSE SW

The EGSE software shall have the capability to pause and shall allow select continuously tests by default. It must have the ability to schedule test start and stop hour, and must allow for cyclic testing.

The reports generated by the software must be in real time and reloaded at the end of the test sequence. All results should be displayed in the test report, even if it has several iterations, which should be less than 3 minutes. It shall be able to display the errors and iterations counted, and to display the voltage drop on the GCCs of each of the MCCM DUMMYS. The acceptance test report must be able to be displayed while the test is being performed, and must have the ability to add tools to it. In addition, the software must have the ability to recover from a failure in one iteration if the unit under test recovers.

### 3.2.4 REPORTING

The reports generated must be saved in .xml format and in non-volatile memory and must show the measurements and results indicated in the test to be performed, the number of iterations and failures, and the time taken to perform the test. It must be able to stop



and continue the test at any time, and it must have a tool capable of filtering and displaying the reports generated by the system.

The ATR shall display information about the Part Numbers and serial numbers of the cables and items used in the test, the version of the software used, and the instrumentation used and its calibration.

### 3.3 External system interface requirements

#### 3.3.1 RFCB

The RFCBs are the PCBs responsible of connecting the DLs to the MCCMS, there are five types of RFCBs (RX, TX, SC, GEO, GEO Mono), and all of them will mount a J1 connector, which will connect to the DL. However, the RX and TX type RFCBs will also mount J2 and J3 connectors, which are not present on the other boards. The layout of these connectors on the RFCBs is given in the picture below:

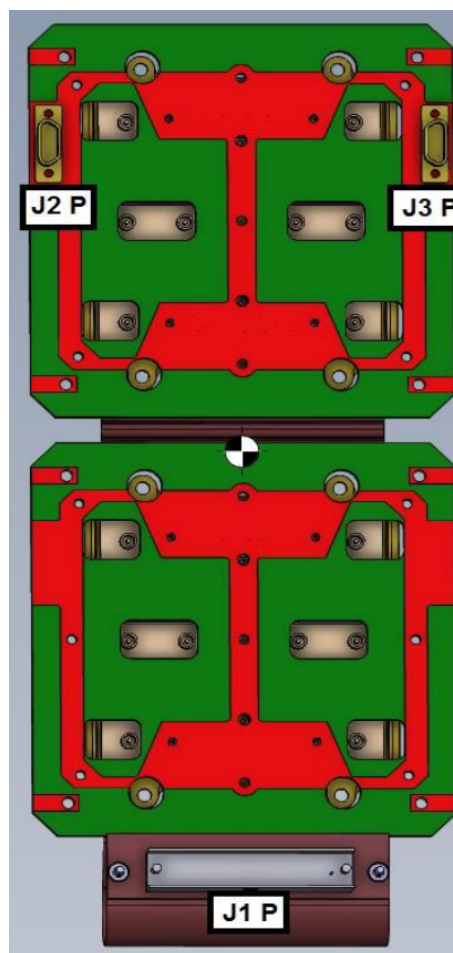


Figure 3.24 – RFCB interface detail

The connectors corresponding to each of these references shall be able to connect to the corresponding connectors of the DLs and MCCMs, and shall be as follows:

RFCB REF.	TO/FROM	CONNECTOR	CONECT TO	RFCBs
J1	DL	MHD1005731114 MHD Male Connector PCB 152 ways	MHD1004631122 MHD Female Connector PCB 152 ways	ALL
J2	Antenna	340102901B15PFR139 MDM Male Connector PCB 15 ways	MDM Female Connector PCB 15 ways	RX,TX
J3	Antenna	340102901B15PFR139 MDM Male Connector PCB 15 ways	MDM Female Connector PCB 15 ways	RX,TX

3

As can be seen, connector J1, as it is connected to the DL, it will be known which connector it will be connected to, however, for J2 and J3 they will have to be searched for during the design phase.

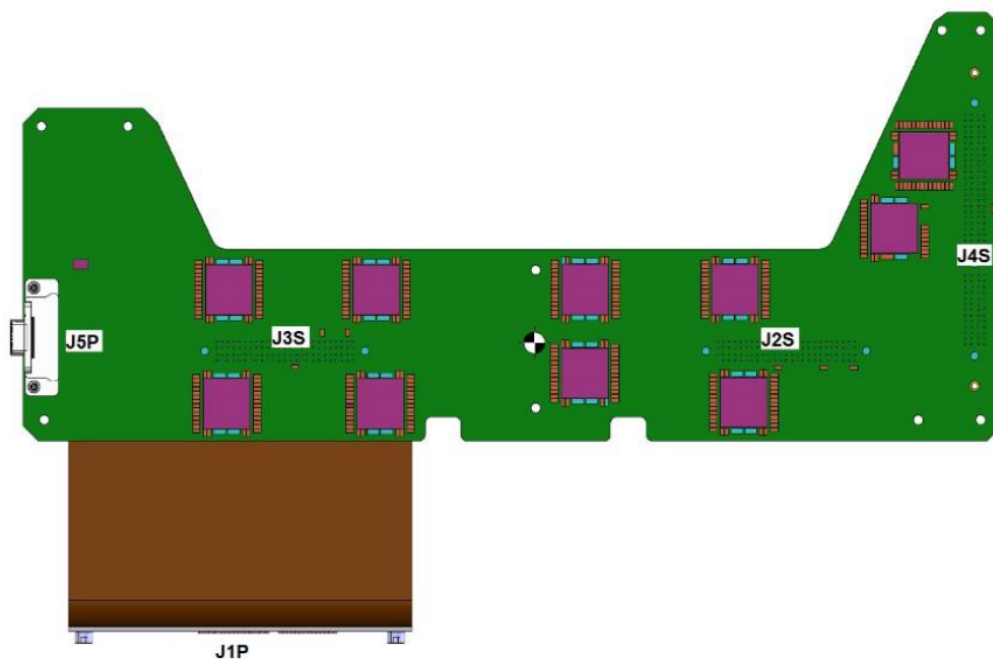
In addition to these connectors, the RFCB BOARD must have an interface to connect to each of the MCCMs via two interposers of 70 pins each.

### 3.3.2 DL

In order to be able to carry out the tests, the EGSE must be able to reach all interfaces of the DLs, which will depend on which type it is:

- **DL HEAD**

In a row of DLs, the first one is always a DL HEAD or DL HEAD MIRROR, which, as they are the first ones, must have more connectors, which will be J1, J2, J3, J4 and J5. J1 is the interface that connects to the DB, J2 and J3 connect to the RFCBs, J4 connects to the DL TAIL and J5 is a test connector. The distribution of these connectors inside the board will be as shown in the following image:



**Figure 3.25** – *DL HEAD interface detail*

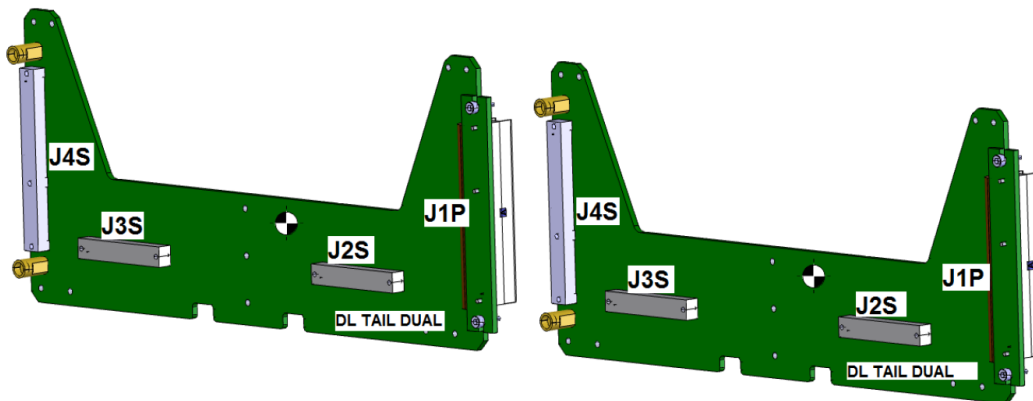
The connectors of this board must be able to maintain connection with the interfaces of the other boards to which they are connected, and shall be:

DL_HEAD INTERFACE	TO/FROM	CONNECTOR	CONECT TO
J1	DB	MHD1005731114 MHD Male Connector PCB 152 ways	MHD1004631122 MHD Female Connector PCB 152 ways
J2	RFCB	MHD1004631122 MHD Female Connector PCB 100 ways	MHD1005731114 MHD Male Connector PCB 100 ways
J3	RFCB	MHD1004631122 MHD Female Connector PCB 100 ways	MHD1005731114 MHD Male Connector PCB 100 ways
J4	DL_TAIL	MHD1004631122 MHD Female Connector PCB 152 ways	MHD1005731114 MHD Male Connector PCB 152 ways
J5	Test	340102901B15PFR136 MDM Male Connector 90° PCB 15 ways	MDM Female Connector PCB 15 ways

As with the RFCBs, we know the connectors where the DB interfaces fit, because they connect to boards whose interfaces we also know. This is not the case with J5, and if we want to connect it, we will have to look for the corresponding connector.

- **DL TAIL DUAL / DL TAIL MONO**

These boards will follow the DL HEAD, and, in case of the DL TAIL DUAL, it may be followed by another DL TAIL DUAL or a DL TAIL MONO. Their interfaces will be the same as those of the DL HEAD, but without the J5 connector in the case of the DL TAIL DUAL, and without the J3, J4 and J5 connectors in the case of the DL TAIL MONO. The distribution of the interfaces on both boards will be as shown in the following image:



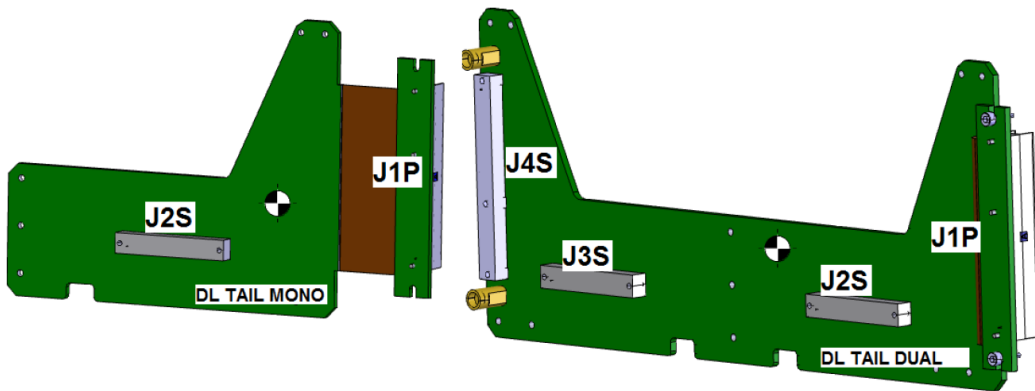


Figure 3.26 – DL TAIL DUAL and DL TAIL MONO interface detail

3

These interfaces will all be connected to known connectors, and therefore no new ones will have to be found. The connectors will be:

DL_TAIL INT.	TO/FROM	CONNECTOR	CONECT TO	DL_TAIL
J1	DL_HEAD / DL_TAIL	MHD1005731114 MHD Male Connector PCB 152 ways	MHD1004631122 MHD Female Connector PCB 152 ways	BOTH
J2	RFCB	MHD1004631122 MHD Female Connector PCB 100 ways	MHD1005731114 MHD Male Connector PCB 152 ways	BOTH
J3	RFCB	MHD1004631122 MHD Female Connector PCB 100 ways	MHD1005731114 MHD Male Connector PCB 152 ways	DUAL
J4	DL_TAIL	MHD1004631122 MHD Female Connector PCB 152 ways	MHD1005731114 MHD Male Connector PCB 152 ways	DUAL

### 3.4 Safety requirements

The EGSE shall be designed in such way, that personnel in charge of operating the system will not be exposed to moving mechanical parts such as gears, fans, and belts. During peak performance of the EGSE, its temperature should not exceed 50°C, and as a method of prevention, the EGSE must have appropriate bonding and earthing. It too must have a circuit breaker and differential to avoid electrical risks, as well as an emergency stop button on the main frame.

### 3.5 Security and privacy requirements

All documentation must be classified as TECNOBIT CONFIDENTIAL. Access must be controlled through the use of users and all documentation must be uploaded to [SAP](#), in the case of documentation related to configuration control; and in [Tortoise SVN](#), for development documentation, software documentation, etc.

### 3.6 Human-factors engineering requirements

The EGSE must have a computer that is in charge of controlling the equipment tests and that has a graphical interface to manage these tests. Regarding the tests, the EGSE must provide vibration tools to support the UUT tests and cables to connect the equipment, as well as a special one for the vacuum chamber.

## 3

### 3.7 Operations and maintenance requirements

The EGSE must be designed to operate for a minimum of 8 hours per day for a full year without maintenance and must have its own calibration plan.

### 3.8 System interface requirements

The EGSE must have savers on the connectors of the UUT to prolong its maximum performance.

#### 3.8.1 System external interfaces

EGSE shall require one-phase 230 V +/- 10%, 50-60 Hz input to power the Test Equipment, and must have an electrical interface to each of the UUTs.

#### 3.8.2 Egse communications interface

EGSE shall provide an external Ethernet connection for general purposes, and shall provide logical interfaces with the different UUTs in accordance with their ICDs.

#### 3.8.3 Egse mechanical interface

The EGSE must have a mechanical interface between the test equipment and the RFCBs, between the test equipment and the DLs, and between the test equipment and the DB.

### 3.8.4 Egse electrical I/O interface

EGSE shall provide an electrical I/O interface with each one of the UUTs according to its electrical ICD

## 3.9 System environmental requirements

The EGSE RACK must be designed to operate under standard laboratory environmental conditions, and both the DB DUMMY BOARDS and MCCM DUMMY BOARDS, and the cables and tools used for the various connections of the UUT must be capable of operating in temperature conditions between  $-40^{\circ}\text{C}$  and  $85^{\circ}\text{C}$ , and ambient pressure conditions less than or equal to 1.33mPa.

### 3.10 Internal data requirements

The data generated by the EGSE should be stored in reports whose numerical data should be given in the International System, and with two decimals where possible. The operating system used for the EGSE must be Windows 10.

### 3.11 Physical requirements

The colour RAL7035 should be used on the EGSE where possible, and the external facilities to power the EGSE should comply with IEC 60309.



(a) *RAL7035 colour*



(b) *IEC60309 connector*

### 3.12 Personal-related requirements

EGSE should be designed to have minimal human intervention. The tester should only be involved if there is no other possible way, and the connectors should have polarisers where possible to avoid any errors when connecting them.

**3**



# EGSE DESIGN

Once the various requirements agreed with ADS<sup>®</sup> have been obtained, it is possible to move on to the design phase. To carry out this phase, the EGSE will be divided into three different parts, the **EGSE boards**, which will be the boards designed at the company that will be used to perform the tests but will not be delivered to ADS<sup>®</sup>; the **EGSE MAINFRAME**, which will be the Rack that will be in charge of performing and controlling the tests; and the **EGSE CABLES**, which will be the cables used to connect the different parts of the EGSE.

The focus of this chapter will be mainly on the design of the **EGSE MAINFRAME** and the **EGSE CABLES**, which will be the parts on which the author has focused his work during his time at the company, as the design of the EGSE boards corresponds to other people.

## 4.1 EGSE boards

The boards that will be delivered to ADS<sup>®</sup> will be the RFCBs and DLs mentioned above, which will be responsible for the distribution of the control and power electronics between the DBs and the MCCMs manufactured by ADS<sup>®</sup>. To verify the correct operation of the boards manufactured by the company, and their adaptation to the satellite, they will have to be tested with the DBs and MCCMs. But because this is a test equipment and we will be working on a development phase, the DBs and MCCMs used at the company will have to be test boards that simulate the functionalities of the boards designed at ADS. As these boards will be for testing purposes, they will be called DB DUMMY and MCCM DUMMY.

In addition to these two boards, the EGSE will have the EIM BOARD, which is the board that will provide the electrical interfaces to the DB DUMMY and will be located inside the main frame.

Since the design of these three boards does not correspond to the author, this section will focus on the characteristics of the boards that will help in the design of the **EGSE MAINFRAME** and the **EGSE CABLES**, such as their dimensions or the position of their connectors.

#### 4.1.1 EIM BOARD

The EIM BOARD, as previously mentioned, is the board that will provide the electrical interfaces to the DB DUMMY. This board will be able to test two lines of UUTs at the same time, the RIGHT line and the MIRROR line. For its operation it will need 3.3V and 5V power supply, and it will have to provide the following signals through its outputs:

- 4x Serial Peripheral Interface (SPI) (Only 1 simultaneously)
- 48 discrete select lines of the RFCBs
- 4x BUS discrete select lines
- 4x nDBUFF digital lines
- 4x nDBUFF\_SC digital lines
- 4x NACT digital lines
- 4x Reset digital lines
- 4x BH clock signals
- 4x Control signals of the EIM BOX sources

The dimensions of this board shall be based on a PCB with dimensions 200mm wide and 200mm long and with the position of its connectors in the following layout:

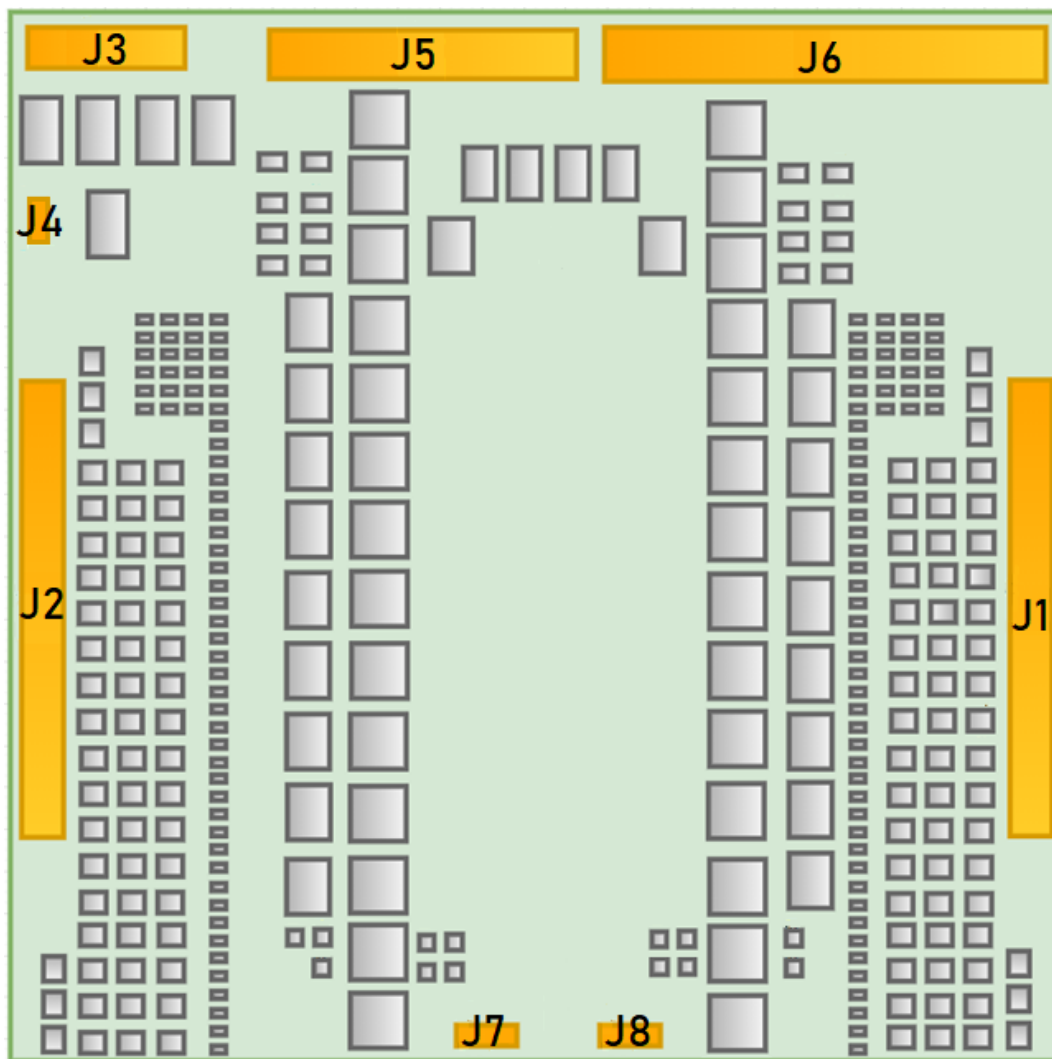


Figure 4.1 – EIM BOARD interfaces detail

The J1 and J2 interfaces are the **321YL120F44H** model connectors from the French company **NICOMATIC**, known for the development and manufacture of connectors for space or defence use, such as this connector, which belongs to the series of high-performance microconnectors. From the name of the model, we can obtain the characteristics of this connector, for this purpose we will have to divide it into different parts:

- **32:** Indicates that the connector will have three rows and will have jackscrew to fix them.
- **1:** Indicates that it is male, if it were female, it would be 2.
- **YL:** Indicates the method of fixing the pins, in this case, through hole straight to the PCB and with a length of 4.5mm.

- **120:** This is the number of contacts that the connector will have.
- **F44H:** Indicates how the connector will be fixed to the PCB.



Figure 4.2 – NICOMATIC logo

These interfaces will be used to transmit the control signals to the DBs. Each of the connectors will go to one line of the UUTs, J1 will go to the RIGHT line, and J2 will go to the MIRROR line.

The J3 interface will be responsible for supplying power to the EIM BOARD, and therefore make it work. The 3.3V and 5V signals that supply the EIM BOARD will enter through this connector, and the signals that control the 3.3V and 5V sources of the EIM BOARD, as well as the 12V and -12V signals that supply the MCCM DUMMYS, will exit through this connector. This connector, part number **83614-9016**, is manufactured by US-based company **MOLEX**. The connector is similar to D-type connectors, such as those commonly used in computer peripherals, but with the feature that this one is high-density and therefore micro-D series, with more contacts in less space. It has 25 male type contacts and jackscrew for attachment to the PCB. The connector will be the same as shown in the image below.

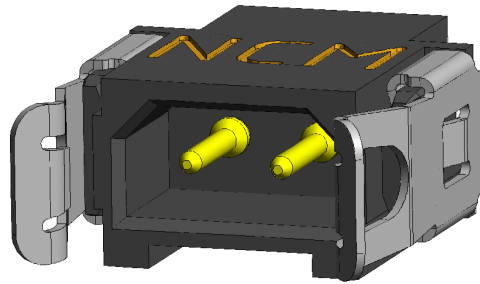


(a) MOLEX logo



(b) 83614-9016 connector

The J4 interface will also be from **NICOMATIC**, but the model will be the **102Y02**, which is a different series to the previously seen connectors from the same manufacturer, and has a row of only two female contacts. This connector will be the one for the cables going to the thermal camera, and one of the contacts will be for the input signal and the other for the output signal.

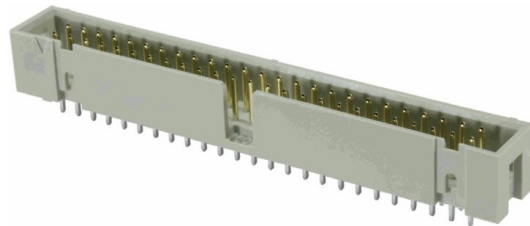


**Figure 4.3** – 102Y02 connector

The J5 interface will be the model **09 18 540 7324** from the company called **HARTING**, and it will be a male connector with 40 pins, which is where the signals will be connected to the **NI USB-8452** unit, which will be a master SPI interface that will generate the MOSI and SCLK signals and will be in charge of reading the MISO signals coming from the MCCM DUMMYS cores.



(a) HARTING logo



(b) 09 18 540 7324 connector

The connector corresponding to J6 will be manufactured by the Swiss company **Tyco Electronics**, and will have 100 female contacts that will be used to transmit the digital control signals from the EIM BOARD to the **NI USB 6509 DIOs**, which will be a module from which the EIM BOARD will generate different control signals such as bus selection signals for the different boards. The connector is the one you can see in the following picture, which, like the D-type connectors, has a polariser so that there are no problems when making the connection with the cable.



(c) TE CONNECTIVITY logo



(d) J6 interface connector

The last interfaces, connectors J7 and J8, will be used to connect to a voltmeter, and, in this way, check that the sources that feed the EIM BOARD are working correctly. They will be male connectors with 4 pins each, two input and two output, it will be manufactured by the company **HARWIN** and the connector will be as follows:

**HARWIN**



(e) HARWIN logo

(f) J7 and J8 interface connector

#### 4.1.2 DB DUMMY

This board will be in charge of distributing all the signals from the EIM BOX of the rack to the DL HEAD and vice versa, and therefore it must be able to fit in with the DL HEAD. The DB DUMMY will have dimensions of 168mm by 270mm and its interfaces will be distributed as follows:

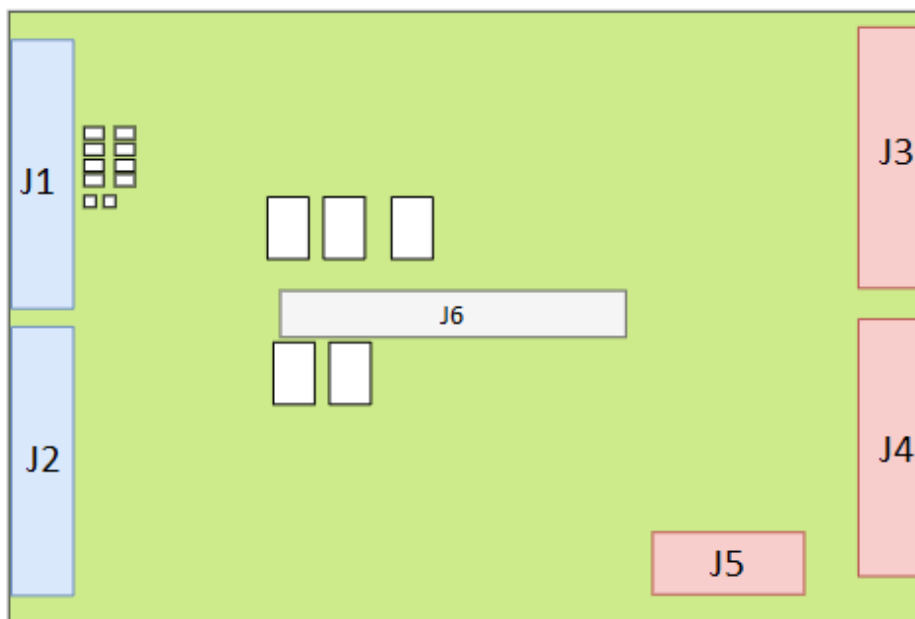


Figure 4.4 – DB DUMMY interfaces detail

The interfaces from J1 up to and including J5 will all be from the same manufacturer, **HARTING**, which has been mentioned earlier in the EIM BOARD. These connectors will

all be Sub-D connectors but with different numbers of contacts. In addition, they will all have a trough-hole connection to the PCB with a 90° connection, except for J5, which will be straight to the PCB.

J1 will be a 62-pin male connector and J2 will be a 62-pin female connector, thus avoiding the possible human error that could be produced by having two identical connectors, and complying with EGSE requirements.



**Figure 4.5** – *DB DUMMY J1 and J2 interfaces detail*

The same goes for J3 and J4, both being 78-pin, J3 has male pins, and J4 has female pins, like is possible to see in the following picture:



**Figure 4.6** – *DB DUMMY J3 and J4 interfaces detail*

J5, however, is a connector that has 26 male-type pin contacts and will be arranged on the PCB straight to the board, as has already been clarified above.



**Figure 4.7** – *DB DUMMY J5 interfaces detail*

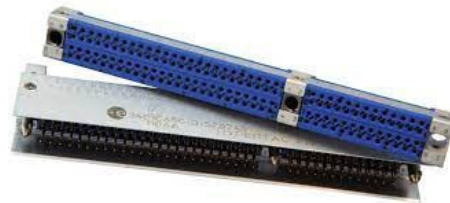
All these mentioned interfaces will be connected to a cable, the W01\_EXT, which has already been mentioned at some point throughout the document, and which will be discussed later in the **EGSE CABLES** section.

J6 is the interface that will connect the DB to the DL HEAD. In the EGSE requirements, it could already be seen that in the DL HEAD section, the DL HEAD connector that connected it to the DB was a connector manufactured by **Smiths Interconnect** from the MHD series and with reference number **MHD1005731114**, which had 152 male pins. Therefore, the connector on the DB to connect the two boards will be the same connector, but with 152

female pins, which has a part number of **MHD1004631122**. These connectors have high performance under high stress conditions, and are therefore recommended by [ESA](#) as suitable for use in space systems. This connector will look like the one shown in the photo below:



(a) SMITHS INTERCONNECT logo



(b) MHD1004631122 connector

### 4.1.3 MCCM DUMMY

This board will be in charge of simulating the functions of the flight model MCCMs manufactured by [ADS](#)<sup>®</sup> in order to test all the functionalities of the RFCBs and DLs. It will be 162mm by 120mm and will be connected to the RFCBs via two 70-pin interposers. Some of the functionalities of the boards manufactured by the company should be: being able to monitor the power delivery rails, connections to the different loads on the board that simulate the real ones, monitoring the interfaces or maintaining communications via SPI. For this purpose, the board will be designed with four **ATMEGA 2560** cores that will have a connector on the board so that they can be programmed. In order for the board to operate, it will need to be powered by 12V and -12V through one of its connector interfaces. The layout of the connectors on the MCCM DUMMY shall be as follows:



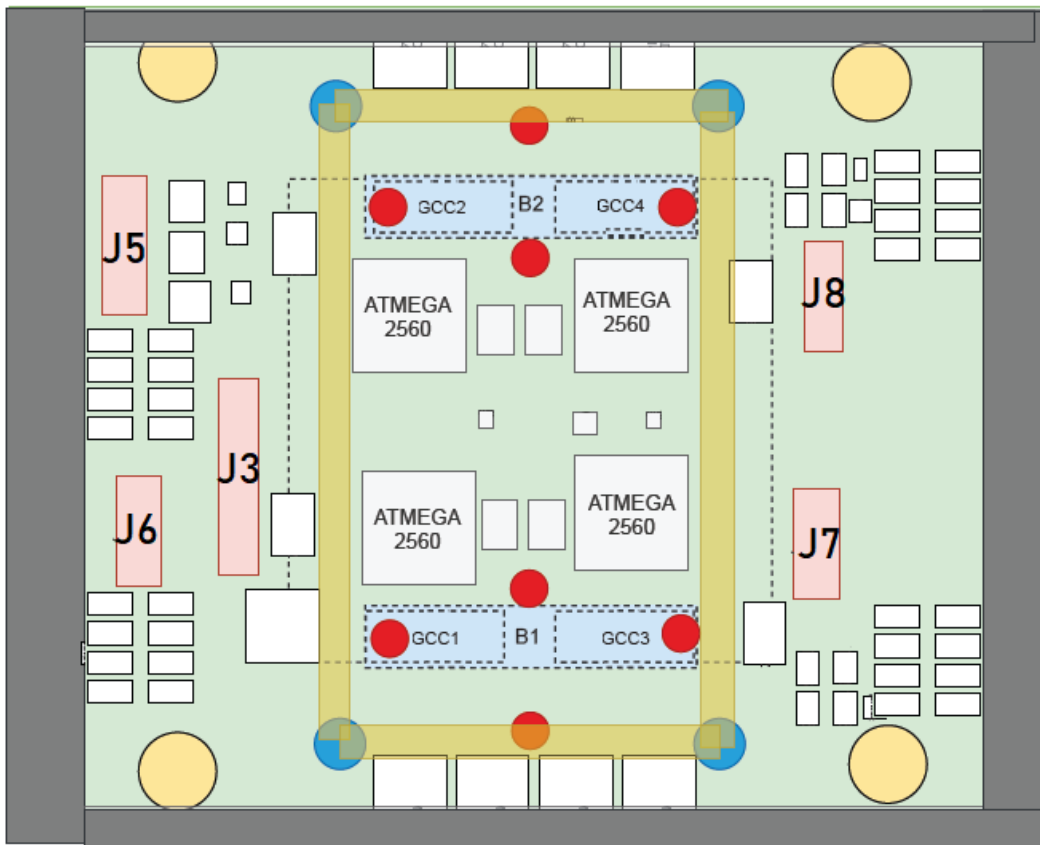


Figure 4.8 – *MCCM DUMMY interfaces detail*

The areas coloured in yellow correspond to areas where the different mechanics of the board will have to be located, and, therefore, no component may be located in that area. In the centre you can see the four **ATMEGA 2560** cores, and at their sides, in blue, the position of the B1 and B2 interposers, which establish the connection between the RFCB and the MCCM DUMMY, and which will look like this:



Figure 4.9 – *MCCM DUMMY interposer detail*

As for the rest of the connection interfaces, J3 will be a male connector manufactured by **SAMTEC** that will have 40 pins distributed in two rows and will be used to connect the **NI USB-8452** programmer to the MCCM DUMMY, in order to configure each of the four cores. The connector located on the board will be the one we can see in the following image:



(a) SAMTEC logo



(b) J3 connector

The J5 interface connector will be responsible for supplying power to the board for operating, and it will be manufactured by **NICOMATIC**, with serial number **221Y10F21**, which as we have already seen indicates that it has two rows of male pins with through hole soldering and 10 pins in total. The connector will have jackscrews to be able to be attached to another connector and to the PCB, and will look like in the following picture:

4



Figure 4.10 – MCCM DUMMY J5 interface detail

The J6 and J7 connectors will be the same and will both go to the J2 and J3 interface of the RFCB respectively, to measure signals on the RFCB. Both connectors will also be manufactured by **NICOMATIC** and will have a reference of **221Y06F21**, which as you can see is the same as the previous connector, but changing the number of pins it will have, which in this case will be 6.



Figure 4.11 – MCCM DUMMY J6 and J7 interfaces detail

The last connector, the J8, will only be used in case of mounting a RFCB DUMMY instead of a RFCB, and although they are also from **NICOMATIC** and have 6 female contacts, their reference will be **222Y06F21** and they will have a rectangular shape, as you can see in the following picture:



**Figure 4.12** – *MCCM DUMMY J8 interface detail*

## 4.2 EGSE mainframe

As mentioned in other chapters, the EGSE MAINFRAME will be the rack that will be in responsible for performing the necessary tests to verify the electrical operation of the UUTs under the corresponding requirements. For this purpose, the EGSE rack will have to be able to generate the power distribution and control signals of the UUTs and the necessary power to operate them. The design of this Rack cannot be started from the outside, just as we do not start building a house from the roof, so we will first analyse the amount of elements that will be necessary for the correct operation of the rack, and later we will decide on the size of the rack.

In the requirements section, the different use cases that will have to be tested by the rack can be seen. It can be seen that the case where more elements are used will be the one corresponding to the use of 3 DLs, one DL HEAD and two DL TAIL DUAL; with all the corresponding RFCBs and MCCMs, six RFCBs and twelve MCCMs. As these lines have a mirror model, the rack will be designed to have the capability to test both RIGHT and MIRROR models at the same time.

For the distribution and control signals we will use the EIM BOARD, board that has been previously named, and that for its installation inside the rack will have to be placed inside a box that will be named EIM BOX. For this board to work, it will be necessary to install two power supplies, one 3.3V and the other 5V, which, depending on their dimensions and the dimensions of the EIM BOARD, can be installed inside or outside the EIM BOX. In reference to other EGSE boards, the MCCM DUMMYS will need a 12V and -12V power supply, so they will have to be installed with two other power supplies that meet these characteristics, which, like those mentioned above, can be installed inside or outside the EIM BOX.

As can also be seen from the requirements, the MCCM DUMMYS of the UUTs have to be able to measure the voltages of the power that is transmitted through the DLs and RFCBs and that correspond to the signals whose names were:

- VDD\_MCCM

- VDD\_SC
- VCC2
- VSS
- VG\_SSPA
- VDD\_LNA

Therefore, for the generation of these different power signals, six sources per line will have to be installed in the Rack, meaning a total of twelve sources.

For the correct operation of the rack, the elements mentioned above would be sufficient, but the EGSE safety requirements indicate that the rack must have a Power Protection Unit (PPU) with a circuit breaker, a differential, and an emergency button.

Even so, these will not be the only components in the rack, as space will still have to be found for different components that are essential for the operation of the rack, such as a switch that takes the information from the computer that controls the equipment to any of the elements in the Rack, or a power strip to supply all these elements. In addition, for the EIM BOARD to work properly, we will have to install a NI USB-8452 module and a NI USB 6509 DIOs module, as we have seen in the design part of this board. As these modules are small, they will not be fitted in the rack, but we will have to assess their installation by inserting them in the EIM BOX, or, as it is normally done, in any DIN rail we want to install. Therefore, we still don't know what the size of the rack will be, but we can start sketching it now.

Racks are widely used in any sector related to communications or electronics, which means that their manufacture is standardized to make it easier for manufacturers to design the modules that will be integrated into them. Racks have three measurements that we are already familiar with: width, height and depth. These three measurements are given in units that do not correspond to the international system, and therefore, we are not used to working with them. The width refers to the distance between the internal profiles of the rack, which will hold the modules. This distance is given in inches, and it is possible to find racks with measurements of 10, 13, 19 inches, etc. on the market. The most commonly used in the telecommunications field, and the size that will be chosen for this rack, is 19 inches. The height refers to how tall the rack is going to be, but not in metres, but in units. A unit or U is going to be the equivalent height of 4.445cm, what happens is that the modules of the Racks are standardised to measure that height or multiples of it. Therefore, from now on, the height of the rack will be measured in Us, which will help us to better understand the number of modules inside the rack, and the size of the rack that we are going to need. The depth of the rack is measured in centimetres, and varies depending on how deep the modules are. In addition, it is important to consider that a space must be left so that the cables connecting the different modules at the back can be bent without forcing them too much.

In conclusion, it is possible to obtain that, for the design of a Rack, the first thing that has to be defined is the width that we want it to have, as the modules are manufactured according to this standardized measurement. The height is not initially the biggest problem, as this will be determined by the number of modules we are going to use and their heights, as well as the depth which, at first sight, is not a blocking factor.

Once the width of the rack has been chosen, 19 inches, it is possible to start choosing the modules of the rack according to the selected width, and start designing it. First, an approximation of the design will be made by choosing all the modules to be used and their order within the rack, and then once these modules have been chosen and the cables have been designed, different parts of the Rack will have to be mechanised so that everything can be well connected.

For this initial approach to the design, and with everything that has been explained previously, the EGSE MAINFRAME could be divided into these large groups:

- EIM BOX
- EGSE BOARDS POWER SUPPLIES
- UUTs POWER SUPPLIES
- DIN RAIL
- LAPTOP
- PPU (Power Protection Unit)
- POWER STRIP

#### 4.2.1 EIM BOX

This Rack module will contain the EIM BOARD and will be the physical interface to which the W01\_EXT is connected, the cable which, as mentioned above, will connect the Rack with the UUTs, and which will be discussed in more detail in the section EGSE CABLES. For this Rack module, the possibility of installing the power supplies that feed the EIM BOARD and the MCCM DUMMYS will also be studied. To obtain the physical characteristics of this module, we will start by knowing the physical characteristics of the EIM BOARD, which is the board that will be inside. As we have seen previously, the EIM BOARD will have dimensions of 200mm by 200mm. As we know that the case is going to be 19 inches wide, the width of the case is going to be 482.6 mm, which means that there is going to be plenty of space in the case when the board is placed.

The EIM BOX will also be the physical interface of the rack, as mentioned above. On the front of the EIM BOX there must be the connectors with which the W01\_EXT fits, as much for the RIGHT line as for the MIRROR line. On this front side there will also be

space to connect other future ports that we are going to need, or the voltmeters of the EIM BOARD that have been previously mentioned. As a preventive measure for heat dissipation, and seeing the space left over when installing the board, we will look for a large rack box, in order to be able to install inside some of the elements that will not be rack modules, but will be essential elements for its operation, such as the power supplies that feed the EIM BOARD and the MCCM DUMMYs. In order to meet these conditions, we will look for Rack boxes with a height of about 5U to guarantee the maximum possible space.

A high-performance rack box will be sought so that there is no mechanical failure during the life of this Rack. Therefore, we will work with the company **RS Components**, which is not only a manufacturer, but also the largest international supplier of industrial products and high-quality electronic components.

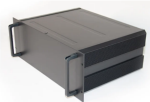

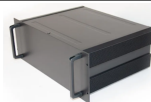



Figure 4.13 – RS Components logo

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At <https://es.rs-online.com/web/> it is possible to find a wide range of useful elements for any industrial or electronic application. [Tecnobit-Grupo Oesia](#) makes weekly orders to this company, which guarantees high performance components for a long period of time.

Using the search bar, it is possible to insert the key words that help to filter the elements in order to find the right one. In this way, typing "19-inch rack box" will bring up all the available models of 19-inch-wide rack boxes, and the option to filter by their characteristics. Filtering by height and selecting the 5U option, the following models appear with the following characteristics:

CODE	188-1324	665-7731	188-1323	665-7649
DIMENSIONS	L: 425	L: 425	L: 425	L: 483
	W: 425	W: 482.6	W: 335	W: 466
	H:217.3	H: 221.5	H: 217.3	H: 222
COLOUR	Black	Black	Black	Grey
MATERIAL	Aluminium	Steel	Aluminium	Aluminium
	Die cast aluminium		Die cast aluminium	Die cast aluminium
PRICE	184.35	112.10	172	80.03
PHOTO				

In terms of dimensions, the four boxes have more or less similar dimensions, especially in

terms of height and width, although for example the box with RS code **188-1323** is smaller in depth than the box with RS code **188-1324**, as they are the same model, but with this small difference. In terms of materials, all the cases are made with an aluminium front panel, and with the body made of extruded aluminium or steel, and although aluminium is cheaper than steel, steel provides greater reliability as it is more durable and more resistant.

Colour is not a determining factor, but it should be remembered that in the EGSE requirements it was made clear that as far as possible the colour **RAL7035** should be used, which is a range of grey, however, only the last box, RS code **665-7649**, is of a similar colour to the one required.

The determining factor in this case will be the price, since as we have seen, they are boxes with very similar characteristics, with the main difference in the material in which they are made and in their price. This is why the box chosen will be the last one, RS code **665-7649**, as it is the one made of the best material, it meets the colour requirements, and it is also the one with the lowest price.

As the dimensions of the box base are 483mm by 466mm, the surface area of the box will be 225.078 mm<sup>2</sup>. The EIM BOARD had dimensions of 200mm by 200mm, and therefore a surface area of 40,000 mm<sup>2</sup>. As the EIM BOARD will be installed horizontally inside the box, this means that there will be 185.078 mm<sup>2</sup> left over in the EIM BOX to install the power supplies for the EGSE boards or any of the other Rack elements mentioned above.

Knowing the available space in the EIM BOX, we will proceed to find the power supplies for the EGSE boards, looking for, if possible, some whose dimensions make them suitable for installation inside the EIM BOX.

#### 4.2.2 EGSE BOARDS POWER SUPPLIES

The EGSE boards are the DB DUMMYS, the MCCM DUMMYS, and the EIM BOARD, but only the latter two need power to operate. The MCCM DUMMYS will need two power supplies, one 12V, and one -12V; while the EIM BOARD will need 3.3V and 5V in order to fulfil its functionality. Since the EIM BOARD has the capacity to control the on/off of these sources, and, in addition, it needs two of them to be able to work, we will look for these sources of the smallest possible size to be able to install them close to the EIM BOARD.

In the previous section, it was calculated that the remaining space of the EIM BOX will be 185,078 mm<sup>2</sup>, which, divided between the 4 power supplies, means an approximate surface area of 46,270 mm<sup>2</sup> per power supply to be installed inside the EIM BOX, although it is clear that, for correct operation, there must be plenty of space inside the box.

Currently, there are two main groups of power supplies on the market: linear power supplies and switched-mode power supplies. Both are capable of transforming alternating current input into direct current output. Linear power supplies work by transforming the input voltage into lower voltage values, and then rectifying and filtering it to convert it into direct current; while switched-mode power supplies are responsible for this transformation

through the use of switching transistors. Linear sources are very robust to noise, but their size is much larger than switch-mode power supplies and their price is higher. Switch-mode power supplies, on the other hand, generate a lot of electronic noise, but have a very high power factor. Due to the size required and taking into account the price of these power supplies, which will not power any of the boards that can be delivered to ADS, but will only power the EGSE boards, it was decided to look for switch-mode power supplies that fit well in the EIM BOX case.

To obtain these power supplies, we will search in the repertoire of power supplies manufactured by the company MEAN WELL, which is a Taiwanese company founded in 1982 and which is the fourth most important in the world in the manufacture of switched-mode power supplies, specialising above all, in the manufacture of enclosed power supplies, which are the type of power supplies that will best adapt to the Rack, as they will have an aluminium casing that will act as shielding and will protect the EIM BOARD from the noise created by this power supply.



Figure 4.14 – MEANWELL logo

On the company's official website, [www.meanwell.com](http://www.meanwell.com), it is possible to find a wide catalogue of different types of power supplies for various uses. In the products section, selecting the AC/DC tab, and clicking on ENCLOSED, all the series of power supplies of this type manufactured by the company will appear. Each of the series will have different models for the required output power, being the nomenclature of the power supplies as follows:

#### XXXX-YYY-ZZZ

**XXXX:** Series of enclosed sources it belongs to

**YYYY:** Amount of output power that the power supply can achieve

**ZZZ:** Output voltage of the power supply.

The different series available are as follows:

- UHP
- EHP
- RS



- LRS
- SE
- PSP
- RSP
- HRPG
- MSP

In order to make the installation of the power supplies easier, and to simplify the software that is used to switch them on and off, the 4 power supplies will be chosen from the same series and model, meaning that the 4 power supplies will have the same **XXXX** and **YYYY** part of the name, only changing the **ZZZ** part that indicates the voltage of each one.

As previously mentioned, the EIM BOARD will be in charge of controlling the switching on and off of the power supplies, so one of the requirements when looking for these is, that they can be switched on and off remotely. To check which series have this function, it will be necessary to open the datasheet of the lowest power model of each of the series, and see in that document if that function exists, since, if the lowest power model does not have remote control, a higher power model will not have it either. Once it is verified that it has the remote-control function, we will see if there are models of power supplies with the necessary voltages, which are: 3.3V, 5V and 12V. It should be noted that, although a -12V supply is required, this is achieved by reversing the polarity on a 12V supply when connecting the output. For this reason, two 12V supplies will be purchased, even if one supplies the boards with +12V and the other with -12V.

By analysing the datasheets of the lower output power models of the above power supply series, it is possible to create a table like the following:

	REMOTE-CONTROL	3.3V	5V	12V	ADEQUATE
UHP		NO	NO	NO	
HEP		NO	NO	NO	
RS		NO	NO	NO	
LRS		NO	NO	NO	
SE		NO	NO	NO	
PSP					
RSP					
HRPG					
MSP					

Looking at the table, it can be seen that the first 5 series of power supplies do not have the possibility of remote control in their lower power model and that is why we discard them



directly. Next, we look at the datasheets of the 4 remaining power supply series to see the output voltage possibilities they have. The **PSP** series is the only one that has models with a 5V and 12V output, but not a 3.3V model, so we also discarded it directly.

Now there are only 3 series of power supplies that have fulfilled all the conditions, which are the **RSP** series, the **HRPG** series, and the **MSP** series. To make this initial analysis, we had taken the models with the lowest power output for each series, assuming that, if the model with the lowest power output did not have these characteristics, a model with higher power output would not have these characteristics either. But these models are not known to be the ones that will be used, as the power delivery required from each source has not been calculated.

For this reason, we will now make an analysis of the power consumption of the boards and determine the power output required from the power supplies.

The 12V power supplies will be the ones that will be providing power to the MCCM DUMMYs, and to make an analysis of the required power to be supplied by the power supplies, we will have to calculate the current that passes through each of the components of the board. This analysis can be found in the **CED** (Consumption Estimation Document) of the MCCM DUMMY, but, as the design of this board does not correspond to the author, only the final results will be shown. Obtaining for the 12V supply a total current of **312,37mA**.

<i>Component Description</i>	<i>Power IN (mA)</i>
Voltage (V)	12
TOTAL CURRENT	312,37
UNITS	mA

Figure 4.15 – MCCM consume

This data corresponds to a single MCCM DUMMY, but knowing that, in the worst case, 24 MCCM DUMMYs will be used, the current is calculated for all the boards. This calculation is simple, as we will only have to multiply the current obtained by 24, thus obtaining the following result:

$$312,37 * 24 = 7496,88 \text{ mA}$$

This value can be approximated to **7,5A**, and from here, we can know the power that the supply will have to be able to provide. We apply the power formula below, and we obtain the power supplied by the source.

$$P = V * I$$

$$P = 12 * 7,5 = 90W$$

The 12V supply will then need to be capable of providing 90W.

Next, the calculation is repeated for the 3.3V and 5V supplies. These supplies will be responsible for powering the EIM BOARD, so as before, an analysis of the board currents is made. We open the **CED** file, and we get the analysis made by the person who was in charge of designing the board. The sum of the currents flowing through each of the board's components will be as follows:

<i>Component Description</i>	<i>5V EIM (mA)</i>	<i>3V3 EIM (mA)</i>	<i>3V3 EGSE (mA)</i>
<b>[Voltage (V)]</b>	<b>5</b>	<b>3,3</b>	<b>3,3</b>
<b>TOTAL CURRENT</b>	<b>523,00</b>	<b>81,00</b>	<b>1505,00</b>
<b>UNITS</b>	<b>mA</b>	<b>mA</b>	<b>mA</b>

Figure 4.16 – EIM BOARD consume

It can be seen that the 5V supply will have to withstand a current of **523 mA**, and the 3.3V supply will have to withstand a current of  $1505 + 81 = \mathbf{1586\ mA}$ . Repeating the calculations made for the 12V source, the following power ratings are obtained:


- 5V SUPPLY:  $0.523 * 5 = \mathbf{2.615\ W}$ .
- 3.3V SUPPLY:  $1.586 * 3.3 = \mathbf{5.23\ W}$ .

Of the three sources that have been calculated, it can be seen that the limiting one is the 12V source, which will require the most power. As explained above, we will choose the three power supplies from the same series and model, so we will look at the models of the three series of power supplies that were left, which are the ones that meet the power and intensity requirements, without forgetting that they must be able to be controlled remotely.

Starting with the **RSP** series, you can see the different models on the website:

» RSP-75~500 Series

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**Wattage :** 75W~500W

**Model**

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**Features :**

- 1U Low profile with active PFC function:  
75W~320W: 30 mm, 500W: 40.5 mm
- Built-in constant current limiting circuit (RSP-75/100/150)
- Built-in remote ON/OFF control (RSP-75/100/150/500)
- Built-in remote sense (RSP-500 only)

**Model**

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: [RSP-75](#) / [RSP-100](#) / [RSP-150](#) / [RSP-200](#) / [RSP-320](#) / [RSP-500](#)

Figure 4.17 – RSP series

As can be seen, this series has models from 75W to 500W output. As we have seen that the 12V supply will need 90W of output power, the first model, the **RSP-75**, is discarded. Then, we read the datasheet of the next model, the **RSP-100**, and check that it meets the requirements.

MODEL		RSP-100-3.3	RSP-100-5	RSP-100-7.5	RSP-100-12	RSP-100-13.5	RSP-100-15
OUTPUT	DC VOLTAGE	3.3V	5V	7.5V	12V	13.5V	15V
	RATED CURRENT	20A	20A	13.5A	8.5A	7.5A	6.7A
	CURRENT RANGE	0 ~ 20A	0 ~ 20A	0 ~ 13.5A	0 ~ 8.5A	0 ~ 7.5A	0 ~ 6.7A
	RATED POWER	66W	100W	101.25W	102W	101.25W	100.5W
	RIPPLE & NOISE (max.) Note.2	100mVp-p	100mVp-p	100mVp-p	100mVp-p	100mVp-p	100mVp-p
	VOLTAGE ADJ. RANGE	3.14 ~ 3.63V	4.75 ~ 5.5V	7.13 ~ 8.25V	11.4 ~ 13.2V	12.8 ~ 14.9V	14.3 ~ 16.5V
	VOLTAGE TOLERANCE Note.3	±2.0%	±2.0%	±2.0%	±1.0%	±1.0%	±1.0%
	LINE REGULATION	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%
	LOAD REGULATION	±1.0%	±1.0%	±1.0%	±0.5%	±0.5%	±0.5%
	SETUP, RISE TIME	600ms, 30ms at full load					
	HOLD UP TIME (Typ.)	16ms at full load					

Figure 4.18 – RSP-100 models

## 4

This model of power supply still has the function of switching on and off by remote control, and seeing the current and power limits, it could be said that they are sources that will serve us for our rack, however, although the sources with 3.3V and 5V outputs more than meet the requirements of power and current, the 12V source has the limit very close to the calculated, being only one amp above, and therefore, to ensure that there are no possible problems in the future, we discard this model and check with the next model, the **RSP-150**.

MODEL		RSP-150-3.3	RSP-150-5	RSP-150-7.5	RSP-150-12
	DC VOLTAGE	3.3V	5V	7.5V	12V
	RATED CURRENT	30A	30A	20A	12.5A
	CURRENT RANGE	0 ~ 30A	0 ~ 30A	0 ~ 20A	0 ~ 12.5A
	RATED POWER	99W	150W	150W	150W


Figure 4.19 – RSP-150 models

In this case, it can be seen that all three power supplies meet the current and power requirements, which ensures correct operation avoiding errors. For this purpose, the **RSP-150** power supply model can now be considered valid for the rack.

The next series, the **HRPG** series, is then evaluated using the same procedure as the previous one. Starting with the models from this series, which are as follows:

» HRP Series

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**Wattage :** 75W~1000W

**Features :**

- Built-in active PFC function
- High efficiency, no load power consumption <0.5W~0.75W
- 5 years warranty

**Model**

Single Output : [HRP-75](#) / [HRP-100](#) / [HRP-150](#) / [HRPG-150](#) / [HRP-200](#) / [HRPG-200](#) / [HRP-300](#) / [HRPG-300](#) / [HRP-450](#) / [HRPG-450](#) / [HRP-600](#) / [HRPG-600](#) / [HRPG-1000](#)

---

**Figure 4.20** – *HRPG series*

This series of power supplies ranges from 75W to 1000W, and as in the previous case, the 75W models are automatically discarded, as 12V power supplies need 90W to ensure they always work. So we begin to analyse the 100W model, the **HRP-100**, by analysing its datasheet and checking that it meets the requirements.

MODEL	HRP-100-3.3	HRP-100-5	HRP-100-7.5	HRP-100-12	HRP-100-15	HRP-100-24
DC VOLTAGE	3.3V	5V	7.5V	12V	15V	24V
RATED CURRENT	20A	17A	13.5A	8.5A	7A	4.5A
CURRENT RANGE	0 ~ 20A	0 ~ 17A	0 ~ 13.5A	0 ~ 8.5A	0 ~ 7A	0 ~ 4.5A
RATED POWER	66W	85W	101.3W	102W	105W	108W

**Figure 4.21** – *HRP-100 models*

As with the previous series, the **RSP** series, this power supply model fulfils the power and current requirements, but the 12V model is close to the calculated value, which is why we discard this model and move on to the next one, the **HRPG-150**.

MODEL	HRPG-150-3.3	HRPG-150-5	HRPG-150-7.5	HRPG-150-12	HRPG-150-15
DC VOLTAGE	3.3V	5V	7.5V	12V	15V
RATED CURRENT	30A	26A	20A	13A	10A
CURRENT RANGE	0 ~ 30A	0 ~ 26A	0 ~ 20A	0 ~ 13A	0 ~ 10A
RATED POWER	99W	130W	150W	156W	150W

**Figure 4.22** – *HRPG-150 models*


It is possible to appreciate that this model of the **HRPG** series fulfils the power and current requirements correctly, ensuring at all times the correct operation of the power supply.

Finally, we analyse the models of the missing series, the **MSP** series, which has models



ranging from 100W to 1000W as can be seen in the following image:

» MSP Series



**Wattage :** 100W~1000W

**Model**

**Features :**

- Medical level, built-in active PFC
- Medical safety approved (MOOP level)
- High efficiency, no load power consumption<0.5W~0.8W

**Model**

: [MSP-100](#) / [MSP-200](#) / [MSP-300](#) / [MSP-450](#) / [MSP-600](#) / [MSP-1000](#)

**Figure 4.23** – *MSP series*

As with the previous series, the datasheet of the lower power model should be analysed to check whether it meets the requirements. The operating conditions of the first model, the **MSP-100**, shall be as follows:

MODEL	MSP-100-3.3	MSP-100-5	MSP-100-7.5	MSP-100-12	MSP-100-15
DC VOLTAGE	3.3V	5V	7.5V	12V	15V
RATED CURRENT	20A	17A	13.5A	8.5A	7A
CURRENT RANGE	0 ~ 20A	0 ~ 17A	0 ~ 13.5A	0 ~ 8.5A	0 ~ 7A
RATED POWER	66W	85W	101.3W	102W	105W

**Figure 4.24** – *MSP-100 models*

As with the previous series, the 100W power model with 12V output has a working range very close to the calculated one, and is therefore discarded, having to analyse the next model, which is the **MSP-200**:

MODEL	MSP-200-3.3	MSP-200-5	MSP-200-7.5	MSP-200-12	MSP-200-15
DC VOLTAGE	3.3V	5V	7.5V	12V	15V
RATED CURRENT	40A	35A	26.7A	16.7A	13.4A
CURRENT RANGE	0 ~ 40A	0 ~ 35A	0 ~ 26.7A	0 ~ 16.7A	0 ~ 13.4A
RATED POWER	132W	175W	200.3W	200.4W	201W

**Figure 4.25** – *MSP-200 models*

This model also satisfies the power and current requirements that we have calculated, and will therefore also be a possible model for the rack.

After the analysis of the three series, it is possible to state that the model of power supply we are looking for the rack will be one of the following:

- RSP-150
- HRPG-150
- MSP-200

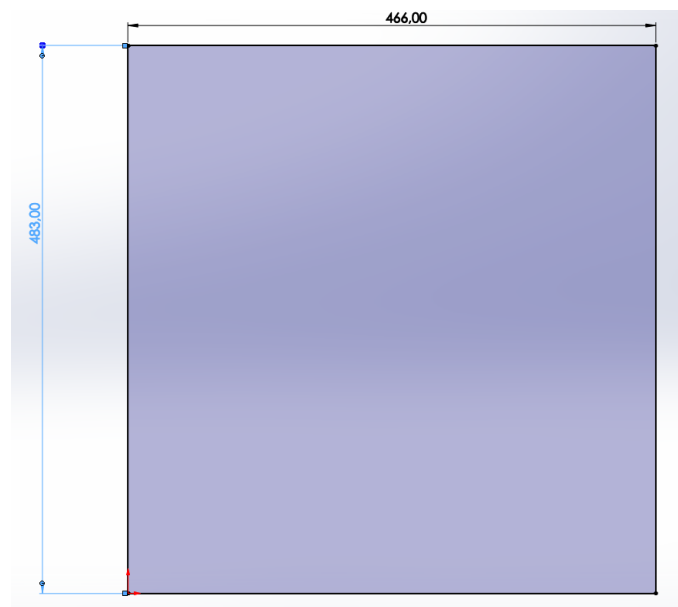
As we have seen, the three series satisfy the functionality requirements established, and will work correctly in the rack, therefore, in order to choose one of the series of power supplies, we will have to evaluate other characteristics, such as seeing if any of these is capable of being installed inside the EIM BOX. For this purpose, we will first have to make a small analysis of the EIM BOX, by locating where the EIM BOARD will be, and then, we will see the available dimensions for each power supply. In order to carry out this analysis, we will work on a sketch made in [Solidworks](#), the industrial design programme of Dassault Systèmes, from which the necessary measurements can be taken with great precision. Screenshots will be used to show the development of the sketch in order to calculate the space required for the supplies.



**Figure 4.26** – *Solidworks logo*

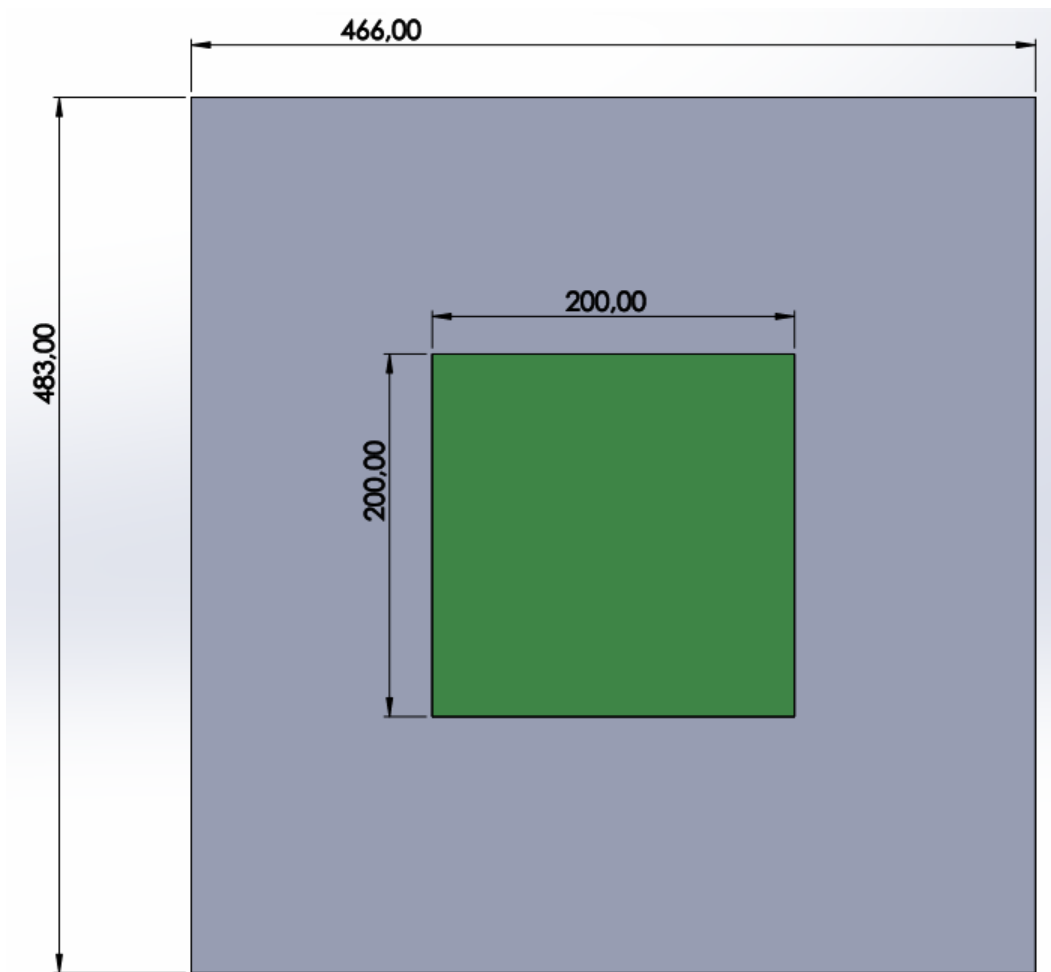
4

The EIM BOX base is a steel panel with dimensions 483x466mm, as shown in the picture below:



**Figure 4.27** – *EIM BOX plan*

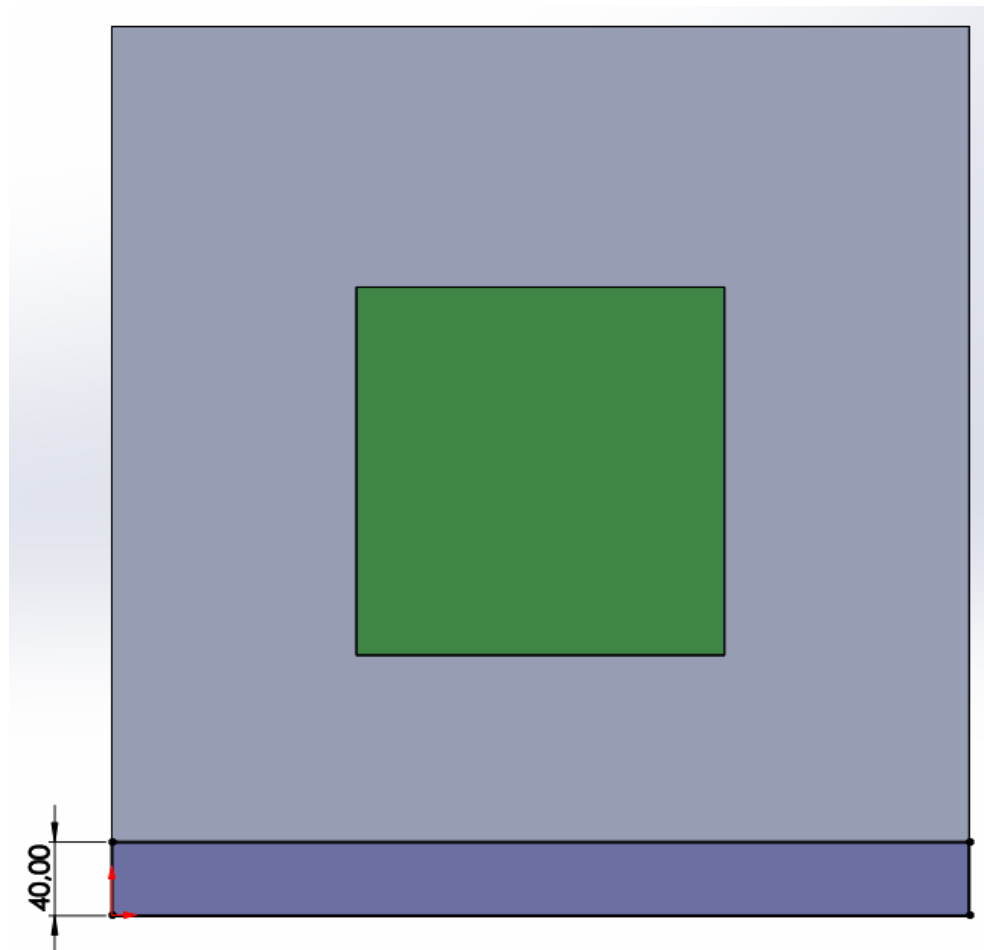
The EIM BOARD, so that all cables can be connected without any problems, will be placed in the centre, with dimensions of 200x200mm, coloured green in the picture:



**Figure 4.28** – *EIM BOARD placed into the EIM BOX*



As different connectors, voltmeters and other elements will be located on the front panel of the EIM BOX, nothing can be placed on the part of the base panel that connects to the front panel, because otherwise the connectors would not be able to be placed. That's why we keep a space of about 40mm in the lower part, and thus, we ensure the correct connection of the components in the front panel:



**Figure 4.29** – *EIM BOX space for the front connectors*

The space in grey will be then the space available to place the fonts. Since the back of the EIM BOX will probably have some cables coming out as well, the placement of the sources will be two on the left side of the EIM BOARD, and two on the right side of the EIM BOARD.

The space available for each source will be then a space like the one marked in red in the following image:

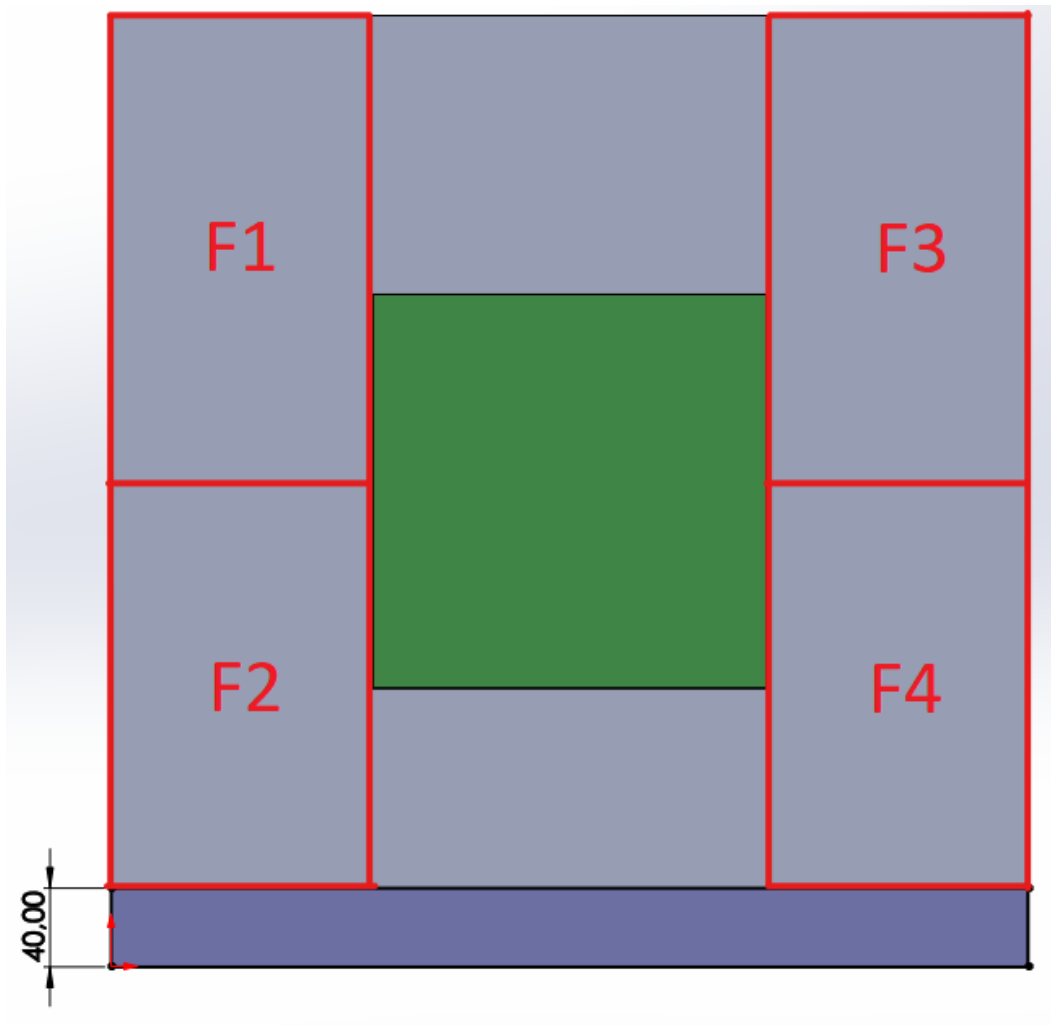
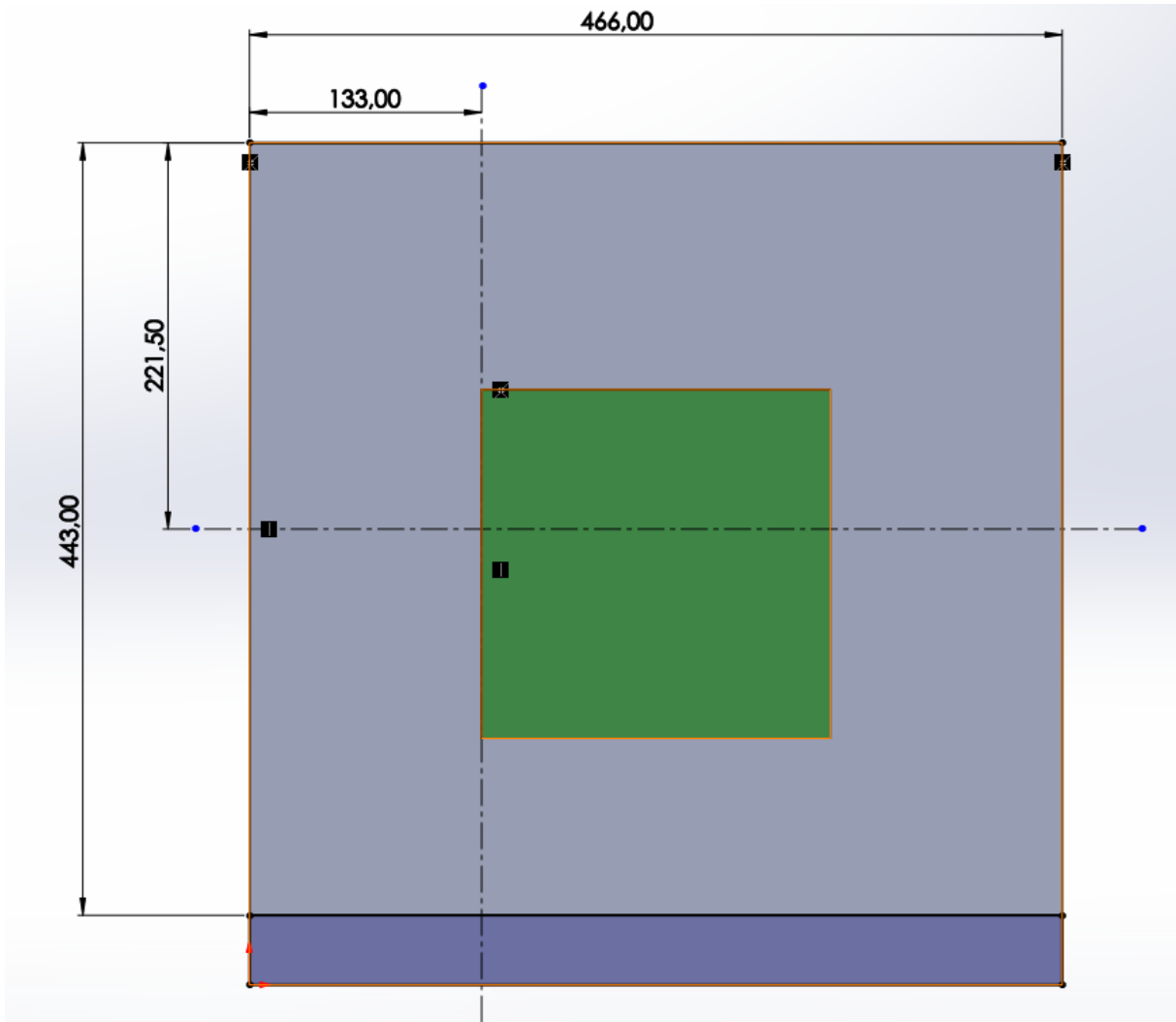


Figure 4.30 – EIM BOX space for power supplies

Thanks to the SOLIDWORKS program, different lines can be drawn to indicate the dimensions of these spaces of the same size, in order to check which series of power supplies fit in the EIM BOX.



**Figure 4.31** – *EIM BOX measures for power supplies*

It can be seen that the space available for each power supply will be 221.50 mm long, 133mm wide, and the height, which will be the height of the EIM BOX, which being 5U, meaning 222mm.

The power supplies will have mechanical attachment to the base on only two of their sides, which are made of aluminium panels. The other sides will be uncovered or will have a grille to protect them from knocks, and, in addition, as they do not have an insulator, they will be the sides through which the electronic noise created by the passive components of the power supplies will be transmitted. As it is important that this noise is as far away as possible

from the EIM BOARD and the internal signal cables of the EIM BOX, the power supplies will be installed in such a way that the side closest to the board is one of the aluminium sides, so that it acts as a shield.

If one of the two aluminium faces will be the one holding the source to the base, and the other will be the one closest to the EIM BOARD, there are only two possible ways to place the sources. In the first way, the sources would be lying on the base of the box, and, therefore, their measurements with respect to the base would be:

	RSP-150	HRPG-150	MSP-200	ESPACIO DISPONIBLE
LARGO	199	159	199	221,5
ANCHO	99	97	98	133
ALTO	30	38	38	222

Analysing the measurements, it can be clearly seen that the height is not an impediment, as it is more than enough. As for the width, all the power supplies have the same width, and although they comply with the available space, it only leaves 30mm of space, which means 3cm, and this could cause some problems if a cable has to pass through this area.

4

To solve this problem, the source can be placed on its side, as there is enough height, so the measurements would be readjusted as follows:

	RSP-150	HRPG-150	MSP-200	ESPACIO DISPONIBLE
LARGO	199	159	199	221,5
ANCHO	30	38	38	133
ALTO	99	97	98	222

In this new form, it can be seen that there is still plenty of space in terms of height, and in terms of width there is now almost 100mm left over. The last measurement to observe is the length, which as we can see, for the **RSP-150** and **MSP-200** series is almost 200mm, which means a free space of only 20mm, meaning 2cm. This measurement would not allow any maneuver to be able to connect the cables to the power supplies, and for this reason, knowing that functionally the three series are the same, it was decided to discard them, choosing then the **HRPG-150** series of power supplies to be installed inside the EIM BOX, and in this way save space.

Once the **HRPG** series and the 150W model have been chosen, the official distributors of the company in Spain are searched in the **MEANWELL** web page, which are identified as **ELECTRONICA OLFER S.L.**

On this company's website it is possible to use the search engine to find the power supplies we want to buy, and by entering '**HRPG-150**' we can find the three models of power supplies we want to use, the **HRPG-150-3V3** model, the **HRPG-150-5** model, and the **HRPG-**

150-12 model.



53,78 €

**HRPG-150-3.3**  
*En existencia*

Entrada: 85-264Vca.  
Salida: 3.3Vcc. 30A.  
Potencia: 99W. PFC.  
ON/OFF remoto.  
5 años de garantía.

Comprar 5 por 51,23 € y *ahorra un 5%*  
Comprar 10 por 48,97 € y *ahorra un 9%*  
Comprar 20 por 47,55 € y *ahorra un 12%*

Cantidad:  [AGREGAR AL CARRITO](#)

Figure 4.32 – HRPG-150-3v3 power supply price



53,78 €

**HRPG-150-5**  
*En existencia*

Entrada: 85-264Vca.  
Salida: 5Vcc. 26A.  
Potencia: 130W. PFC.  
ON/OFF remoto.  
5 años de garantía.

Comprar 5 por 51,23 € y *ahorra un 5%*  
Comprar 10 por 48,97 € y *ahorra un 9%*  
Comprar 20 por 47,55 € y *ahorra un 12%*

Cantidad:  [AGREGAR AL CARRITO](#)

Figure 4.33 – HRPG-150-5 power supply price



53,78 €

**HRPG-150-12**  
*En existencia*




Entrada: 85-264Vca.  
Salida: 12Vcc. 13A.  
Potencia: 156W. PFC.  
ON/OFF remoto.  
5 años de garantía.

Comprar 5 por 51,23 € y *ahorra un 5%*  
Comprar 10 por 48,97 € y *ahorra un 9%*  
Comprar 20 por 47,55 € y *ahorra un 12%*

Cantidad:  [AGREGAR AL CARRITO](#)

Figure 4.34 – HRPG-150-12 power supply price

All of them with a price of €53.78, would mean an after-tax cost of **€259.52** for the four sources.

PRODUCTO	PRECIO	CANTIDAD	SUBTOTAL
 HRPG-150-12 <small>Código: MW-1949</small>	53,62 €	2	107,24 €
 HRPG-150-5 <small>Código: MW-2235</small>	53,62 €	1	53,62 €
 HRPG-150-3.3 <small>Código: MW-2234</small>	53,62 €	1	53,62 €

[VACIAR CESTA](#)      [ACTUALIZAR LA CESTA](#)    [CONTINUAR COMPRANDO](#)

**ESTIMAR ENVÍO E IMPUESTOS**

PAÍS +     ESTADO/PROVINCIA +     C. POSTAL +

[ESTIMAR](#)

**Sus medios**

*Sus medios* - 0,00 €

**Envío**

*Portes Olfer* - 0,00 €

**ACTUALIZAR EL TOTAL**

SUBTOTAL	214,48 €
MANIPULACIÓN Y ENVÍO (ENVÍO - PORTES OLFER)	0,00 €
IMPUESTOS	45,04 €
<b>TOTAL GENERAL</b>	<b>259,5208 €</b>

**REALIZAR PEDIDO**

Figure 4.35 – Power supplies price

### 4.2.3 UUTs POWER SUPPLIES

These sources are responsible for generating the power to be transmitted through the DLs and RFCBs to the MCCM DUMMYS. As these signals will have to be measured in the MCCM DUMMYS and will be monitored during the tests performed, it is essential that they are not affected by the electronic noise of the passive components, for this purpose, linear sources will be chosen instead of switched-mode sources, which are more expensive, but are better insulated against noise, giving more robustness to the transmitted signals.

Before choosing the power supplies, an analysis of the power consumption of the boards will be made, since, as in the previous section, the current and power provided by the power supply will be a key factor in the choice of the power supply.

Provided by ADS<sup>®</sup>, the consumption of each type of MCCM in the satellite is obtained, with the results shown in the following table:

	RAIL	VOLTAGE (V)	CURRENT (A)	QTY.
DSSPA	Vg_SSPA	-4	0.033	2 per RFCB-TX (i.e. 240)
DLNA	VDD_LNA	5	0,1108	2 per MCCM (i.e. 240)
MCCM TX	VDD_MCCM	4,2	0,67	1 per MCCM (i.e. 120)
	VCC (VSS)	-3,3	0,051	1 per MCCM (i.e. 120)
	VCC2	-1,5	0,063	1 per MCCM (i.e. 120)
MCCM SC TX	VDD_MCCM	4,2	2,33	1 per MCCM (i.e. 8)
	VCC (VSS)	-3,3	0,04	1 per MCCM (i.e. 8)
	VCC2	-1,5	0,0334	1 per MCCM (i.e. 8)
MCCM RX	VDD_MCCM	4,2	0,67	1 per MCCM (i.e. 120)
	VCC (VSS)	-3,3	0,051	1 per MCCM (i.e. 120)
	VCC2	-1,5	0,033	1 per MCCM (i.e. 120)
MCCM SC RX	VDD_MCCM	4,2	2,33	1 per MCCM (i.e. 8)
	VCC (VSS)	-3,3	0,04	1 per MCCM (i.e. 8)
	VCC2	-1,5	0,033	1 per MCCM (i.e. 8)
MCCM GEO	VDD_MCCM	4,2	1,188	1 per MCCM (i.e. 12)
	VCC (VSS)	-3,3	0,02	1 per MCCM (i.e. 12)
	VCC2	-1,5	0,0013	1 per MCCM (i.e. 12)

Figure 4.36 – MCCM consumption

Knowing the number of MCCMs used for each of the distribution line configurations, the maximum consumption of each of the sources can be obtained. For example, for the first type, there will be one RFCB GEO, with two MCCM GEO; four RFCB RX, with two MCCM TXs each; and one RFCB SC, with two MCCM SCs. By analysing the lines passing

through each of the boards, a table like the following can be made:

Tipo 1	Board	DL Head		DL Tail 1			DL Tail 2		
	RFCB Type	GEO	RX	RX	RX	RX	RX-SC		
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)	
DL Currents	VDD_MCCM	2376	1340	1340	1340	1340	0	7736	
	VDD_SC	0	0	0	0	0	4660	4660	
	VDD_LNA_in	0	444	444	444	444	0	1776	
	VSS	40	102	102	102	102	80	528	
	VCC2	2,6	66	66	66	66	66,8	333,4	
	Vg_SSPA	0	0	0	0	0	0	0	

Figure 4.37 – Line type 1 consumption

As the consumption given by ADS<sup>®</sup> is calculated as a function of the MCCMs, to obtain the total, the consumption of the line is multiplied by the number of MCCMs in that configuration, that is, two if it is a normal RFCB that has two MCCMs, or one if it is an RFCB MONO. As in most cases there is only one rail per MCCM, to calculate the consumption it is enough to multiply by the two MCCMs that the RFCB has, but, for rails like VDD\_LNA, which has two rails per MCCM, the value obtained by ADS<sup>®</sup> will have to be multiplied by 4. Adding the data obtained for each RFCB, the maximum consumption per configuration is obtained, and repeating this same analysis for each of the configurations we obtain the following tables:

Tipo 2	Board	DL Head		DL Tail 1			DL Tail 2		
	RFCB Type	GEO MONO	RX	RX	RX	RX	RX-SC		
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)	
DL Currents	VDD_MCCM	1188	1340	1340	1340	1340	0	6548	
	VDD_SC	0	0	0	0	0	4660	4660	
	VDD_LNA_in	0	444	444	444	444	0	1776	
	VSS	20	102	102	102	102	80	508	
	VCC2	1,3	66	66	66	66	66	331,3	
	Vg_SSPA	0	0	0	0	0	0	0	

Figure 4.38 – Line type 2 consumption



Tipo 3	Board	DL Head		DL Tail 1		DL Tail 2		
	RFCB Type	RX	RX	RX	RX	RX	GEO	
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)
DL Currents	VDD_MCCM	1340	1340	1340	1340	1340	2376	9076
	VDD_SC	0	0	0	0	0	0	0
	VDD_LNA_in	444	444	444	444	444	0	2220
	VSS	102	102	102	102	102	40	550
	VCC2	66	66	66	66	66	2,6	332,6
	Vg_SSPA	0	0	0	0	0	0	0

Figure 4.39 – Line type 3 consumption

Tipo 4	Board	DL Head		DL Tail 1		DL Tail 2		
	RFCB Type	RX	RX	RX	RX	RX	GEO MONO	
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)
DL Currents	VDD_MCCM	1340	1340	1340	1340	1340	1188	7888
	VDD_SC	0	0	0	0	0	0	0
	VDD_LNA_in	444	444	444	444	444	0	2220
	VSS	102	102	102	102	102	20	530
	VCC2	66	66	66	66	66	1,3	331,3
	Vg_SSPA	0	0	0	0	0	0	0

Figure 4.40 – Line type 4 consumption

Tipo 5	Board	DL Head		DL Tail 1		DL Tail 2		
	RFCB Type	RX	RX	RX	RX	RX	RX	
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)
DL Currents	VDD_MCCM	1340	1340	1340	1340	1340	1340	8040
	VDD_SC	0	0	0	0	0	0	0
	VDD_LNA_in	444	444	444	444	444	444	2664
	VSS	102	102	102	102	102	102	612
	VCC2	66	66	66	66	66	66	396
	Vg_SSPA	0	0	0	0	0	0	0

Figure 4.41 – Line type 5 consumption

Tipo 6	Board	DL Head		DL Tail 1		DL Tail 2		
	RFCB Type	TX	TX	TX	TX	TX-SC	NONE	
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)
DL Currents	VDD_MCCM	1340	1340	1340	1340	0	0	5360
	VDD_SC	0	0	0	0	4660	0	4660
	VDD_LNA_in	0	0	0	0	0	0	0
	VSS	102	102	102	102	80	0	488
	VCC2	126	126	126	126	66,8	0	570,8
	Vg_SSPA	66	66	66	66	0	0	264

Figure 4.42 – Line type 6 consumption

Tipo 7	Board	DL Head		DL Tail 1		DL Tail 2		
	RFCB Type	TX	TX	TX	TX	TX	NONE	
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)
DL Currents	VDD_MCCM	1340	1340	1340	1340	1340	0	6700
	VDD_SC	0	0	0	0	0	0	0
	VDD_LNA_in	0	0	0	0	0	0	0
	VSS	102	102	102	102	102	0	510
	VCC2	126	126	126	126	126	0	630
	Vg_SSPA	66	66	66	66	66	0	330

Figure 4.43 – Line type 7 consumption

Tipo 8	Board	DL Head		DL Tail 1		DL Tail 2		
	RFCB Type	TX	TX	TX	TX	TX	TX	
	Rail	RFCB 1	RFCB 2	RFCB 3	RFCB 4	RFCB 5	RFCB 6	Total (mA)
DL Currents	VDD_MCCM	1340	1340	1340	1340	1340	1340	8040
	VDD_SC	0	0	0	0	0	0	0
	VDD_LNA_in	0	0	0	0	0	0	0
	VSS	102	102	102	102	102	102	612
	VCC2	126	126	126	126	126	126	756
	Vg_SSPA	66	66	66	66	66	66	396

Figure 4.44 – Line type 8 consumption

Once the analysis of each of the configurations has been done, the maximum values of each rail are studied:

Type	Antenna	Sheet	Total Current (mA)					
			VDD_MCCM (4,2V)	VDD_SC (4,2V)	VDD_LNA (5V)	VCC(VSS) (-3,3V)	VCC2 (-1,5V)	Vg_SSPA (-10V)
1	RX	Type 1	7736	4660	1776	528	333	0
2	RX	Type 2	6548	4660	1776	508	331	0
3	RX	Type 3	9076	0	2220	550	333	0
4	RX	Type 4	7888	0	2220	530	331	0
5	RX	Type 5	8040	0	2664	612	396	0
6	TX	Type 6	5360	4660	0	488	571	264
7	TX	Type 7	6700	0	0	510	630	330
8	TX	Type 8	8040	0	0	612	756	396
<b>MAX para cada media línea</b>			<b>9076</b>	<b>4660</b>	<b>2664</b>	<b>612</b>	<b>756</b>	<b>396</b>

Figure 4.45 – *Maximum consumption per line*

After the analysis, we obtain that, for each of the following lines, the following voltage and current values will be required:

	VOLTAGE (V)	CURRENT(A)	POWER(W)
VDD_MCCM	4,2	9,076	38,12
VDD_SC	4,2	4,66	19,572
VDD_LNA	5	2,664	13,32
VCC (VSS)	-3,3	0,612	2,0196
VCC2	-1,5	0,756	1,134
Vg_SSPA	-10	0,396	3,96

With the current and voltage limitations in place, the next step is to find the sources to supply this power. As the rack has to be designed to work with two lines at the same time, but these two lines do not have to have the same configuration, we will have to look for sources for both lines; and since there are 6 different types of voltage, this means that we will have to look for 12 sources to be able to supply the whole system.

For this task, we will work with the company **KEYSIGHT TECHNOLOGIES**, which is the leading company in the development and manufacture of instrumentation used in the technology sector, and whose measurement and signal generation tools are among the most reliable on the market.



Figure 4.46 – *Keysight Technologies logo*

On the company's website, <https://www.keysight.com/es/en/home.html>, you can find out about the different technologies offered by the American company and the projects they are working on. At the top, in the **PRODUCT+SERVICES** tab, you will find all the products that the company has, and by selecting **Generators, Sources + Power**, you will find the DC Power Supplies section, which is where you will find the resources that are necessary for the rack.

In this section of the page, **KEYSIGHT** provides a catalogue of all the types of power supplies available and their characteristics, so that you can choose the model that best suits the parameters of the rack. Depending on the intended use of the power supplies, there are three types: **BENCH POWER SUPPLIES**, **DC POWER SOLUTIONS**, and **ATE SYSTEM POWER SUPPLIES**. The first two are power supplies to be used for bench testing and for use in different systems, while the last one, however, are power supplies that are designed to be installed in racks. Within **ATE SYSTEM POWER SUPPLIES** there is also a wide variety of series depending on the power that needs to be distributed, which, as can be seen on the website, are as follows:



**Figure 4.47** – *Power supplies series*

Of the available series, it can be seen from the description that they all reach very high-power ranges and have only one output, with the exception of the first series, the **N6700** series, which is the one that can provide the least power, but has the advantage of having four outputs instead of one. This series has models of power between 400W and 1200W, or in other words, an average of 100W to 400W per output.

In the analysis that had been done previously, it could be seen that the power that will be needed in this case will not exceed 100W at any time, so these power supplies will be able to work perfectly with the needs of the rack.

Going back to the **KEYSIGHT** document where you can find all the power supply models, and looking at page 17, you can see all the models of the **N6700** series. This page specifies a little more about the characteristics of this series of power supplies, such as the size of the power supplies, which is 1U; the capacity to be controlled by a computer and to be programmable, or that this series is made up of a mainframe with 4 slots where you can place power supply modules to suit the needs of each one.

Depending on the total power to be dissipated by the mainframe, there are three types of mainframes to choose from:

### N6700 low-profile modular power system mainframe

Model	Power (W)	Max # modules
N6700C	400	4
N6701C	600	4
N6702C	1200	4

**Figure 4.48** – *Mainframes models*

As mentioned above, as it does not exceed 400W in any of the cases, the **N6700C** model will be chosen.

The following document lists all the models of modules that can be installed in the mainframe and the characteristics of each one. As none of the modules will have to exceed 100W of power, only the first 12 models will be of interest:

Model	Power (W)	Maximum V (V)	Maximum I (A)	Number of outputs	Number of slots occupied	Number of ranges	Ripple and noise mVp-p	Programming accuracy % + mV	Transient response ( $\mu$ s)
N6731B	50	5	10	1	1	1	10	0.1 + 19	< 200
N6732B	50	8	6.25	1	1	1	12	0.1 + 19	< 200
N6733B	50	20	2.5	1	1	1	14	0.1 + 20	< 200
N6734B	50	35	1.5	1	1	1	15	0.1 + 35	< 200
N6735B	50	60	0.8	1	1	1	25	0.1 + 60	< 200
N6736B	50	100	0.5	1	1	1	30	0.1 + 100	< 200
N6741B	100	5	20	1	1	1	11	0.1 + 19	< 200
N6742B	100	8	12.5	1	1	1	12	0.1 + 19	< 200
N6743B	100	20	5	1	1	1	14	0.1 + 20	< 200
N6744B	100	35	3	1	1	1	15	0.1 + 35	< 200
N6745B	100	60	1.6	1	1	1	25	0.1 + 60	< 200
N6746B	100	100	1	1	1	1	30	0.1 + 100	< 200

Figure 4.49 – Power supplies models

For each of the powers studied above, the most suitable module will be analysed.

- **VDD\_MCCM:** 4.2 V / 9.076 A

Looking at the list of available module models, it is possible to see that the **N6731B** model, which is 50W, satisfies the voltage and current limits, but both are very close to the limit, so it is discarded, and we are looking for one of the 100W models that fulfils the limits without any problems. The model chosen will be the **N6742B**, which, as can be seen, has a large margin with respect to the calculated values.

N6736B	50	100	0.5	1	1	1	30	0.1 + 100	< 200
N6741B	100	5	20	1	1	1	11	0.1 + 19	< 200
N6742B	100	8	12.5	1	1	1	12	0.1 + 19	< 200
N6743B	100	20	5	1	1	1	14	0.1 + 20	< 200
N6744B	100	35	3	1	1	1	15	0.1 + 35	< 200

Figure 4.50 – N6742B module specifications

- **VDD\_SC:** 4,2 V / 4,66 A

In the list it is possible to find several models that comply with the limits, but the one with the highest range of compliance is the 50W model **N6732B**.

Model	Power (W)	Maximum V (V)	Maximum I (A)	Number of output	Number of slots occupied	Number of range	Ripple and noise mVp-p	Programming accuracy % + mV	Transient response ( $\mu$ s)
N6731B	50	5	10	1	1	1	10	0.1 + 19	< 200
N6732B	50	8	6.25	1	1	1	12	0.1 + 19	< 200
N6733B	50	20	2.5	1	1	1	14	0.1 + 20	< 200
N6734B	50	35	1.5	1	1	1	15	0.1 + 35	< 200
N6735B	50	60	0.8	1	1	1	25	0.1 + 60	< 200

Figure 4.51 – N6732B module specifications

- **VDD\_LNA:** 5 V / 2,664 A

As with the previous voltage, although the **N6731B** model meets the calculated limits, it does so very closely, and so we selected the **N6732B** model which meets the limits more comprehensively.

- **VCC(VSS):** -3,3 V / 0,612 A

At this voltage, we can consider the same models as in the two previous ones, and on this occasion they both fully comply with the power limits, but the **N6732B** model is chosen, as it complies with the voltage limit more extensively.

- **VCC2:** 1,5 V / 0,756 A

For this voltage, all 50W models, with the exception of the last one, satisfy the calculated limits, but the model that satisfies both limits most uniformly is again the **N6732B** model, which is why we chose it for this voltage as well.

- **Vg\_SSPA:** 10 V / 0,396 A

This voltage no longer meets the limits of the previously used model, so we are looking for a new one that does, such as the **N6733B** model, which meets the voltage and current limits by a large margin.

Model	Power (W)	Maximum V (V)	Maximum I (A)	Number of outputs	Number of slots occupied	Number of ranges	Ripple and noise mVp-p	Programming accuracy % + mV	Transient response ( $\mu$ s)
N6731B	50	5	10	1	1	1	10	0.1 + 19	< 200
N6732B	50	8	6.25	1	1	1	12	0.1 + 19	< 200
N6733B	50	20	2.5	1	1	1	14	0.1 + 20	< 200
N6734B	50	35	1.5	1	1	1	15	0.1 + 35	< 200
N6735B	50	60	0.8	1	1	1	25	0.1 + 60	< 200
N6736B	50	100	0.5	1	1	1	30	0.1 + 100	< 200

Figure 4.52 – N6733B module specifications

Once you have selected the models of the mainframes and modules, on the **KEYSIGHT TECHNOLOGIES** page you are asked to select the distributor through which you want to make the purchase, one of these distributors is **RS technologies**, which has been mentioned in previous chapters.

## 4

To facilitate the purchase, by accessing the website <https://es.rs-online.com/web/> and typing in the search engine each of the components we have selected in this chapter, we obtain the total price to be paid for them.

The list of items to buy will be as follows:

- 3x 4 slots Mainframe with reference: **N6700C**
- 2x Power modules with reference: **N6742B**
- 8x Power modules with reference: **N6732B**
- 2x Power modules with reference: **N6733B**

In addition to this, the website offers the possibility to buy a universal kit for mounting KEYSIGHT power supplies in the rack for the price of **62,83€** each. This kit will help the correct installation of the power supplies in the rack, and will ensure the full performance of these.



The price of all the elements in total will be **18277.64€**, as shown in the image below:

The screenshot displays a shopping cart with the following items:

- Item 1:** Módulo de energía Keysight Technologies N6732B, 1 salida/s, 0 → 8V, 6.25A, 50W. Código RS: 690-9641. Fabricante: Keysight Technologies. Nº ref. fabric.: N6732B. Estado RoHS: Exento. Precio unitario: 531,00 €. Total: 4.248,00 €.
- Item 2:** Módulo de energía Keysight Technologies N6733B, 1 salida/s, 0 → 20V, 2.5A, 50W. Código RS: 690-9650. Fabricante: Keysight Technologies. Nº ref. fabric.: N6733B. Estado RoHS: Exento. Precio unitario: 531,00 €. Total: 1.062,00 €.
- Item 3:** Kit de montaje en rack Keysight Technologies 34190A. Código RS: 501-291. Fabricante: Keysight Technologies. Nº ref. fabric.: 34190A. Estado RoHS: No aplicable. Precio unitario: 62,83 €. Total: 188,49 €.

The cart summary shows:

- Total productos: 15.105,49 €
- Entrega: Gratuito
- IVA: 3.172,15 €
- Total del pedido: 18.277,64 €**

Buttons at the bottom include: Imprimir cesta, Guardar cesta, Compartir cesta, and Continuar con el pedido.

Figure 4.53 – Power supplies final price

#### 4.2.4 DIN-RAIL

As we have seen, most of the modules that are installed in a rack have a standardised size for easy installation; they are usually large and heavy modules that fit perfectly into the rack dimensions.

However, there are some elements that are indispensable for the operation of the rack, but which do not have a standardised size for installation in the rack because they are not commonly used, or because they are simple elements whose size is very small.

For the installation of these elements, DIN-rails are usually installed, which is a metal bar with a standardised size, where electrical protection elements, such as circuit breakers or magneto-thermal circuit breakers, are usually placed.

In fact, for the rack's power protection unit, which we will see later, rails of this type will also be used, as it facilitates the installation and replacement of elements in the rack.

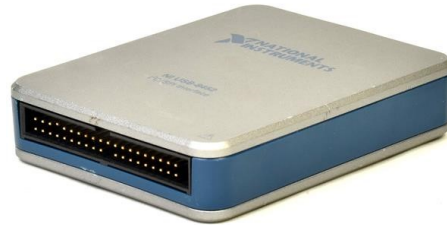
Before choosing the DIN rails to be used, the elements that remain to be chosen for the operation of the rack must be analysed and selected, which are as follows:

- **USB-SPI:** To be used for the control of the EIM BOARD and has been mentioned previously.
- **USB-DIOs:** Like the previous one, it will be used to control the EIM BOARD.
- **SWITCH ETHERNET:** A switch will be needed to distribute the commands from the computer to the rack components, and vice versa.
- **HUB USB:** necessary for communications from the computer to the **USB-SPI** and **USB-DIOs**.
- **POWER SUPPLY:** To power the **SWITCH ETHERNET** and the **HUB USB**.

##### 4.2.4.1 USB-SPI

This rack module will be the interface between the computer and the EIM BOARD during SPI communications, and, as mentioned in the section on the design of the EIM BOARD, will be a model manufactured by the American company National Instruments (NI), and will have a reference of **USB-8452**.

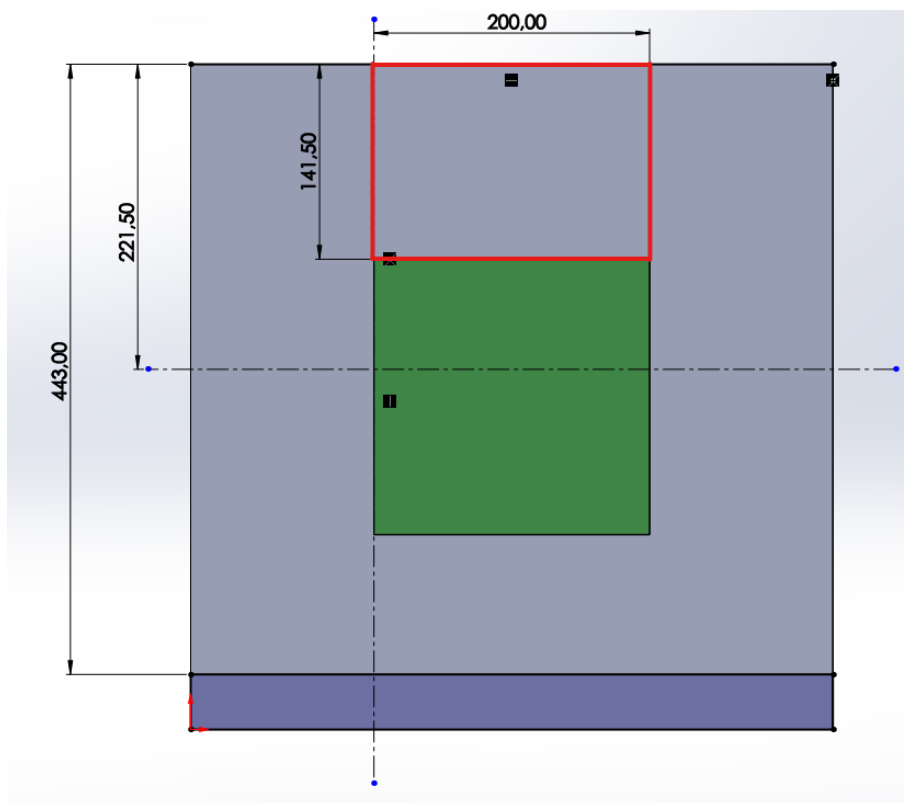
This model is available with a casing to ensure its durability, and will be the one shown in the following image:



© Artisan Technology Group

**Figure 4.54** – *USB-8452 model*

This model has dimensions of  $7.26 \times 9.19 \times 2.03$  cm, and because of its small size, it has the advantage that it can be installed inside the EIM BOX. To check this, the sketch of the base of the EIM BOX, which was used during the design of the supplies inside the EIM BOX, is used again, and the dimensions of the space where the USB-SPI would be placed are entered:



**Figure 4.55** – *Space of the EIM BOX for the USB-SPI*

In the picture above you can see that there is enough space for the USB-SPI to be installed inside the EIM BOX, without disturbing any of the other components. On the National Instruments website you can buy the **USB-8452** with the possibility of adding hardware and software accessories, but in this case you will not need any kind of accessories apart from the case that protects it, obtaining a price as shown below:



□ USB-8452 € 783,00 3.33 MHz 50 MHz Si

Modelo: **USB-8452**  
 Número de Parte: 781964-03  
[Ficha Técnica y Especificaciones](#)

€ 783,00  
 1  
 VER ACCESORIOS  
 Añadir al Carro

**Figure 4.56** – *USB-8452 price*

#### 4.2.4.2 USB-DIOs

4

This module will control external digital devices such as the solid-state relays of the EIM BOARD, and, like the USB-SPI, will be manufactured by **National Instruments**. This device has the ability to be programmed as an input or output port and will have 96 ports. The serial-number is **USB-6509**, and it looks like the one in the image below:



**Figure 4.57** – *USB-6509 model*

The dimensions of this device according to its datasheet are 17.78 x 10.30 x 3.34 cm, so because of this, it cannot be installed inside the EIM BOARD. Therefore, this device will be the first to be installed on the DIN rail, and it will be placed vertically, which will make it more stable, occupying a space on the DIN-rail of 10.3 cm.

Checking the availability of the device on the NI website, you can see the possibility to buy it for the price indicated below:



**Figure 4.58** – *USB-6509 price*

#### 4.2.4.3 SWITCH ETHERNET

A switch is a device that is responsible of routing the data traffic between the ports of the switch. The ethernet switch that will be installed in the rack will be responsible for connecting the different modules that can be controlled from the laptop with it, and also connect all these devices to the network so that the rack has an internet connection.

The main characteristic that defines an ethernet switch is the number of ports it has, and by analysing the modules that will need an ethernet connection to work, the following results are obtained:

- 1 port that is connected to the computer, which will be the one that communicates with the modules.
- 3 ports for the three mainframes of the supplies, so that they can be controlled remotely.
- 1 port connected to the internet network that is responsible of providing connection to the computer.

With this, a total of 5 ports are calculated for the Ethernet switch. As in this case, no sensitive information will be transmitted through the switch for testing the boards, and the amount of information to be transmitted through it is not very large, a 5-port switch available in the company's stock and manufactured by the Taiwanese company **MOXA** will be used.

This switch will be the **EDS-205A** model, which has already been used in other projects of the company and which presents an optimum performance for the needs of the rack,

operating in temperatures ranging from  $-10^{\circ}\text{C}$  and  $60^{\circ}\text{C}$ , and with an easy installation on DIN-rail by using some clips on the back. The switch looks like the one in the image below:



**Figure 4.59** – *EDS-205A model*

It has dimensions of 3 x 11.5 x 7 cm, occupying a space of 3 cm on the DIN rail, and for its operation, the switch requires a 24 V supply with a current of 0.1 A, which is connected to the switch through a terminal block located at the top.

The switch is available at the page of the company, with a price of **88.17€**.

**MOXA**<sup>®</sup>



## EDS-205A

Moxa 5 port entry level unmanaged Ethernet switch w/(5) 10/100BTX ports (IP30 aluminum housing)


Our Price: \$104.00

**Availability:** Usually Ships in 24 Hours

Product Code: EDS-205A

See any errors on this page?

Please let us know.

 Larger Photo

**Add To Cart**

**Figure 4.60** – *EDS-205A price*

#### 4.2.4.4 HUB-USB

A hub is a device that connects multiple devices to one device at the same time. In this case, its function will be to connect via USB the PC that controls the rack, with the two devices that work via USB, which are the USB-SPI and the USB-DIOs. For this element, we will be working with the Canadian company **STARTECH**, which specialises in the manufacture and development of interconnection equipment, and with whom the company has worked in the past.



**Figure 4.61** – *STARTECH* logo

On the **STARTECH** website, <https://www.startech.com/>, you can filter according to your needs. In this case, select the additional boards and peripherals tab under the products, and click on USB 3.0 boards and USB 3.0 hubs. Once you have chosen the USB 3.0 hubs, filter by the industrial ones, which will be those that have been designed for business use.

Once this is done, it is possible to view six different models, in which there are two 4-port models, two 7-port models, and two 10-port models. All models include a mounting bracket with screws to attach it to the wall, but the one of interest for the rack is the DIN rail mount, which is only included in the 7-port and 10-port models. This leaves only 4 models available, which are as follows:

	HB30A10AME	<i>Su precio</i>
	<b>Hub Concentrador Ladrón USB de 10 Puertos con Adaptador de Corriente - con Protección contra Descargas - Hub Industrial de Transferencia de Datos USB 3.0 - de Montaje en Pared Riel DIN o Mesa - Hub US</b> de Tipo Industrial   15kV por Aire   8kV por Contacto   de Metal   Instalable   de Carril DIN   5Gbps	<b>€268,99</b> EUR excl. VAT <b>€325,48</b> EUR incl. VAT



HB30A7AME

**Hub Concentrador Ladrón USB de 7 Puertos con Adaptador de Corriente - con Protección contra Descargas - Hub de Industrial de Transferencia de Datos USB 3.0 - de Montaje en Pared Riel DIN o Mesa - Hub**

de Tipo Industrial | 15kV por Aire | 8kV por Contacto | de Metal | Instalable | de Carril DIN | 5Gbps

*Su precio***€202,99** EUR excl. VAT**€245,62** EUR incl. VAT

ST1030USBM

**Hub Industrial de 10 Puertos USB 3.0 con Protección Antiestática ESD y Protección de Picos de 350W**

de Tipo Industrial | 15kV con Aire | Contacto de 8kV | Metal | de Montaje | para Riel DIN | 5 Gbps

*Su precio***€225,99** EUR excl. VAT**€273,45** EUR incl. VAT

ST7300USBME

**Hub Industrial de 7 Puertos USB 3.0 con Protección Antiestática ESD y Protección de Picos de 350W**

de Tipo Industrial | 15kV con Aire | Contacto de 8kV | Metal | de Montaje | para Riel DIN | 5 Gbps

*Su precio***€164,99** EUR excl. VAT**€199,64** EUR incl. VAT

**Figure 4.62** – *HUB-USB models*

For this rack only 3 ports are needed, so the number of ports is not a key factor in this case, as there will be enough in all cases. The transmission speed can be seen to be the same in all models and therefore will not be a determining factor when choosing the model. As can be seen, the four models are very similar to each other, and therefore, the only determining factor when choosing them would be the price, which can be seen to change a lot from one model to another.

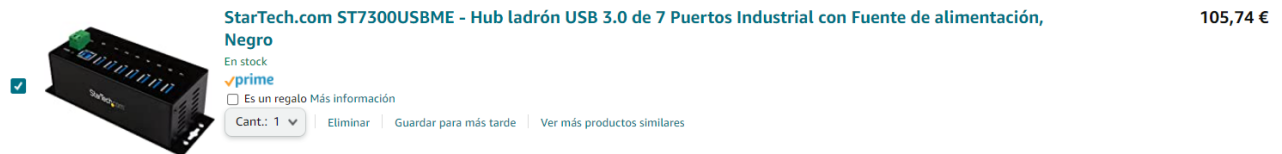


That is why, the model **ST7300USBME** is chosen, which requires a voltage ranging from 7V to 48V for its operation, and has dimensions of 14.5 x 5.4 x 4.5 cm, occupying a total of 5.4 cm on the DIN rail. It is also priced at **€105.74** on Amazon, which is one of **STARTECH**'s distributors in Spain.

### Cesta

Anular la selección de todos los artículos

Precio



StarTech.com ST7300USBME - Hub ladrón USB 3.0 de 7 Puertos Industrial con Fuente de alimentación, Negro

En stock

prime

Es un regalo Más información

Cant.: 1 | Eliminar | Guardar para más tarde | Ver más productos similares

105,74 €

**Figure 4.63** – HUB-USB price

#### 4.2.4.5 POWER SUPPLY

In order to supply power to the HUB USB and the SWITCH ETHERNET, it will be necessary to have a power supply that is small in size and can be installed on a DIN rail. As seen in the previous sections, the HUB USB in the rack will need a voltage between 7V and 48V to work, and the SWITCH ETHERNET will need 24V to work. Since the voltage of the SWITCH ETHERNET is the one that limits both components, we will look for a source that has 24V, which will make both of them work without any problem.

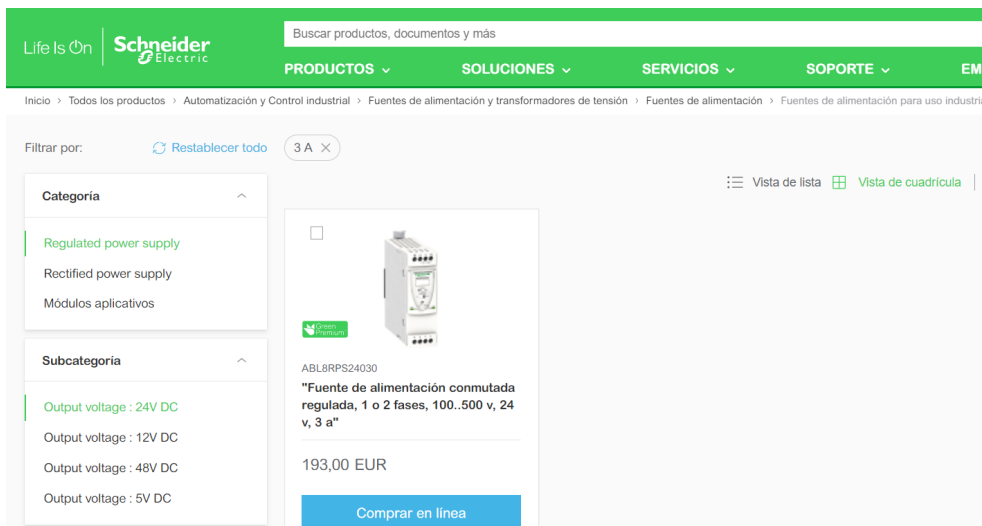
Now, we will have to make an analysis of the amount of current that the power supply must be able to supply. As we have seen in the SWITCH ETHERNET section, it will need 0.1A to be able to work. In the case of the HUB USB, it works with USB 3.0, and, as they are not ports for powering devices, but for data transfer, in the worst case, it will have a consumption of 900mA per port, or 0.9A. Taking into account that only 3 ports of the HUB USB will be used, it can be assumed that in the worst case, the maximum consumption of the HUB USB will be  $0.9A \times 3 \text{ ports} = 2.7A$ . Adding the consumption of both devices, the minimum current that the power supply will have to provide will be  $2.7 + 0.1 = 2.8A$ .

The power supply that is going to be needed will have to be able to supply 24V and 2.8A, and for this purpose we will work with the French company **SCHNEIDER ELECTRONICS**, which is a leading company in the sector of power control accessories for racks, such as circuit breakers, differentials or power supplies that are installed in these.



**Figure 4.64** – SCHNEIDER ELECTRIC logo

Inside the **SCHNEIDER ELECTRONICS** website, it is possible to find an infinite number of useful elements for a rack and DIN rail installation, but to search for the power supply, it is necessary to click on the products tab, and, once opened, to select the option "power supplies for industrial use" inside the "Automation and industrial control" section. Using the filters on the left, it is possible to work with the conditions that we consider necessary, and, introducing an output voltage of 24V, and an output current of 3A, which is the closest value to 2.8A, all the models that are not useful are then filtered out and the one that best fits our conditions appears.



**Figure 4.65** – Available models on the web site

This model, the **ABL8RPS24030**, fulfils the established requirements, and its dimensions according to its datasheet will be 12.5 x 12.5 x 4.5 cm, occupying a space of 4.5cm on the DIN-rail. For its operation, it will need to be connected to a normal power socket through some terminals on the top of the device. Its price will be **193€**, and it will be distributed through the company's different distributors in Spain.



**Figure 4.66** – ABL8RPS24030 model

#### 4.2.4.6 DIN-RAIL

By analysing how much space each of the modules occupies on the DIN-rail, the following calculations are obtained:

<b>MODULE</b>	<b>OCCUPIED SPACE (cm)</b>
USB_DIOs	10.3
SWITCH_ETHERNET	3.0
HUB_USB	5.4
FUENTE_ALIMENTACION	4.5
<b>TOTAL</b>	<b>23.2</b>

The DIN rail must have a length equal to the width of the rack, so, as this is a standardised measurement and is 19", the length of the DIN rail will be 48.26cm, giving plenty of space for all the elements to be installed without disturbing each other. This means that you will only need to buy a 19" DIN rail to fit these elements.

Regarding the height that this rail will occupy, it will be given by the maximum height of its components, which, being in a vertical position, will be as follows:

<b>MODULE</b>	<b>OCCUPIED HEIGHT (cm)</b>
USB_DIOs	17.78
SWITCH_ETHERNET	11.5
HUB_USB	14.5
FUENTE_ALIMENTACION	12.5
<b>MAXIMUM</b>	<b>17.78</b>

The height of the DIN rail will then be 17.78cm, which is 7 inches, which, when converted to rack height units, is 4U.

As a DIN rail is standard, and the difference between one and the other will be minimal, we will look on the RS Components website for one that is 19" long, which is the only limiting feature. On the website you can find an infinite number of types of DIN rails for racks in the "DIN Rails" section of the "Components for Enclosures and Racks" section in the "Boxes, Cabinets and Enclosures" section. With the possibility of filtering by length, by choosing 483mm, which is the width of the rack, you will get a single article.

Ocultar filtros

1 Products

Filtros aplicados (1)

Longitud **ELIMINAR**

483mm ×

**BORRAR TODOS**

Fabricante ▾

Compatibilidad ▾


Datos del Producto	Precio
 <p><b>Carril DIN Siemens, dim. 483mm x 482.6mm x 35mm</b></p> <p>Código RS: <a href="#">203-4164</a> Nº ref. fabric.: 6ES5710-8MA11</p>	<p><b>55,00 €</b> Unidad</p> <p><b>Añadir</b> <input type="button" value="-"/> 1 <input type="button" value="+"/> </p>

Figure 4.67 – DIN-CARRIL price

This is a DIN rail manufactured by the German company **SIEMENS**, and which meets the rack length conditions. Two such DIN rails will be ordered, one for all the elements discussed above, and one for the power protection unit, which will be discussed below. This gives a total price for both of them of **110€**.

### 4.2.5 LAPTOP

Although this module will not be located inside the rack, it will be the element that controls it and will be connected to the inside of the rack. Due to the wide range of computers available, and knowing the use that will be given to it, which is only for testing, it will be chosen for this module a model that has been used in other projects with similar tests, and which is known inside the company.

This model will be the **Satellite Pro C50-E** from the Japanese company **Dynabook**, formerly **TOSHIBA**. This model has 8Gb of RAM and 256Gb of SSD memory, running under an 8th generation i5 processor, more than enough specifications for the work the computer is going to do.



Figure 4.68 – *Satellite Pro C50-E photo*

The price of this computer in the official TOSHIBA shop in Spain is **689€** as can be seen in the following picture:

The screenshot shows the official Dynabook website for Spain. At the top, there is a navigation bar with the Dynabook logo, the text 'TOSHIBA Tienda Oficial España', and a search bar. Below the navigation bar, the breadcrumb trail reads 'Inicio > Portátiles > Toshiba Dynabook Satellite Pro C50-E-103'. The main content area features a large image of the laptop on the left and product details on the right. The product name is 'Toshiba Dynabook Satellite Pro C50-E-103'. The specifications listed are: 'Procesador Intel® Core™ i5-8250U', '8 GB DDR4 2400 MHz', '256GB SSD M.2 SATA', '15,6" Full HD LED 16:9', and 'Windows 10 Home 64 Bits'. Below the specifications, there are two buttons: 'Más detalles' and 'Añadir al comparador de productos'. At the bottom of the product details, the price is displayed as '689,00€ IVA incluido' and 'Gastos de envío: GRATIS'.

Figure 4.69 – *Satellite Pro C50-E price*

### 4.2.6 POWER PROTECTION UNIT (PPU)

This part of the rack will be responsible for protecting the rack in the event of overvoltage or short-circuit through the use of circuit breakers, differential switches and an emergency stop button.

This rack module will be designed based on the design of previous projects, since, although the rack elements change from one project to another, the protection unit will be similar in all of them as it is responsible for protecting the rack as a unit, and it is independent of the system under test.

First, an analysis of the power consumption of the entire rack must be performed. For this purpose, the consumption of each of the rack elements connected to the electrical network must be analysed, which are:

- EGSE BOARDS POWER SUPPLIES
- UUTs POWER SUPPLIES
- DIN-RAIL POWER SUPPLY
- LAPTOP

These four elements are basically those that are connected to the electrical network, and through which the power is distributed across all the elements of the EGSE.

An approximate analysis of the power that will be consumed by each of the above elements is performed.

- **EGSE BOARDS POWER SUPPLIES**

To know what these supplies consume, we will have to see the power that they will distribute to the rest of the equipment, and we will have to see the efficiency with which they work. By collecting the power to be supplied by each source, we obtain a table like the following:

SOURCE	POWER(W)
HRPG-150-12	90
HRPG-150-12	90
HRPG-150-5	2,615
HRPG-150-3.3	5,23

Now we will have to observe in the datasheets of each of the power supplies the power efficiency with which we are working, in order to obtain the real power consumed by the power supplies. This is because the power supplies do not convert all the input power into output power, because it is dissipated through different passives or as heat.

As all power supplies have the same datasheet, it is only necessary to look at the datasheet of the HRPG-150 series, and by looking at it, the efficiency of all power supplies can be obtained:

SPECIFICATION		HRPG-150-3.3	HRPG-150-5	HRPG-150-7.5	HRPG-150-12	HRPG-150-15	HRPG-150-24
OUTPUT	MODEL	HRPG-150-3.3	HRPG-150-5	HRPG-150-7.5	HRPG-150-12	HRPG-150-15	HRPG-150-24
	DC VOLTAGE	3.3V	5V	7.5V	12V	15V	24V
	RATED CURRENT	30A	26A	20A	13A	10A	6.5A
	CURRENT RANGE	0 ~ 30A	0 ~ 26A	0 ~ 20A	0 ~ 13A	0 ~ 10A	0 ~ 6.5A
	RATED POWER	99W	130W	150W	156W	150W	156W
	RIPPLE & NOISE (max.) Note.2	80mVp-p	80mVp-p	100mVp-p	120mVp-p	150mVp-p	150mVp-p
	VOLTAGE ADJ. RANGE	2.8 ~ 3.8V	4.3 ~ 5.8V	6.8 ~ 9V	10.2 ~ 13.8V	13.5 ~ 18V	21.6 ~ 28.8V
	VOLTAGE TOLERANCE Note.3	± 2.5%	± 2.5%	± 2.5%	± 1.5%	± 1.5%	± 1.5%
	LINE REGULATION	± 0.5%	± 0.5%	± 0.5%	± 0.3%	± 0.3%	± 0.2%
	LOAD REGULATION	± 1.0%	± 1.0%	± 1.0%	± 0.5%	± 0.5%	± 0.5%
SETUP, RISE TIME	3000ms, 50ms	230VAC	3000ms, 50ms/1	5VAC at full load			
HOLD UP TIME (Typ.)	16ms/230VAC		16ms/115VAC	at full load			
INPUT	VOLTAGE RANGE Note.5	85 ~ 264VAC	120 ~ 370VDC				
	FREQUENCY RANGE	47 ~ 63Hz					
	POWER FACTOR (Typ.)	PF>0.95/230VAC	PF>0.95/115VAC	at full load			
	EFFICIENCY (Typ.)	78.5%	84%	86%	87%	87%	87%
	AC CURRENT (Typ.)	1.7A/115VAC	0.9A/230VAC				

Figure 4.70 – HRPG-150 series efficiency



In the picture it can be seen that the efficiency obtained from the sources is 78.5% for the 3.3V source, 84% for the 5V source, and 87% for the two 12V sources.

Knowing that the formula for efficiency is:

$$\text{EFFICIENCY} = \text{OUTPUT POWER} / \text{INPUT POWER}$$

You can clear and obtain the equation as a function of the output power and efficiency, which are the two elements that are known, obtaining then the following formula:

$$\text{INPUT POWER} = \text{OUTPUT POWER} / \text{EFFICIENCY}$$

Completing the above table with the values obtained from the datasheet, and operating, the following table is obtained:

SUPPLY	OUTPUT POWER(W)	EFFICIENCY	INPUT POWER(W)
HRPG-150-12	90	0,87	103,45
HRPG-150-12	90	0,87	103,45
HRPG-150-5	2,615	0,84	3,11
HRPG-150-3.3	5,23	0,785	6,67

In total, the sources inside the EIM BOX consume 103.45 + 103.45 + 3.11 + 6.67 = 216.68W.

- **UUTs POWER SUPPLIES**

As with the previous supplies, an analysis of the power to be distributed should be made, and then the efficiency formula previously used should be used.

SUPPLY	POWER(W)
VDD_MCCM	38,12
VDD_SC	19,572
VDD_LNA	13,32
VCC (VSS)	2,0196
VCC2	1,134
Vg_SSPA	3,96

Now, it is necessary to analyse the datasheets of the sources, but, as in the previous case, it is a single datasheet for all the models in the series, and looking at this one, it is not clear what the efficiency is, but the power factor indicates that it is the ratio between the input and the transmitted power, so we take the power factor as the efficiency in this case, and we obtain the following:

AC input	
Input ratings	~ 100 VAC – 240 VAC; 50/60/400 Hz
Power consumption	1000 VA (N6700C) 1440 VA (N6701C) 1440 VA (N6702C @ < 180 VAC input) 2200 VA (N6702C @ > 180 VAC input)
Power factor	0.99 @ nominal input and rated power

**Figure 4.71** – UUTs power supplies efficiency

With an efficiency of 99%, and adding it to the above table as done previously, we apply the efficiency formula and obtain the following result:

SUPPLY	INPUT POWER(W)	EFICIENCY	OUTPUT POWER(W)
VDD_MCCM	38,12	0,99	38,51
VDD_SC	19,572	0,99	19,77
VDD_LNA	13,32	0,99	13,45
VCC (VSS)	2,0196	0,99	2,04
VCC2	1,134	0,99	1,15
Vg_SSPA	3,96	0,99	4,00



The total power consumed by all the supplies in a line is **78.92W**, but as the rack has to be prepared to support two lines at the same time, both together will consume  $78.92 * 2 = 157.84W$ .

- **DIN CARRIL POWER SUPPLY**

As in the previous sections, the datasheet of the power supply should be consulted in order to know how much power it consumes.

#### Complementary

Input voltage limits	170...550 V 85...132 V
Network frequency	47...63 Hz
Inrush current	<= 30 A for 2 ms
Cos phi	0.51 at 240 V 0.59 at 120 V
Efficiency	87...100 %
Output voltage limits	24...28.8 V adjustable
Power dissipation in W	7.8 W
Line and load regulation	1...3 %

**Figure 4.72** – *DIN CARRIL power supply efficiency*

In the datasheet it says that the efficiency of the power supply is between 87% and 100%, and to prevent future problems, an efficiency of 87% is assumed, which will prevent unexpected consumption.

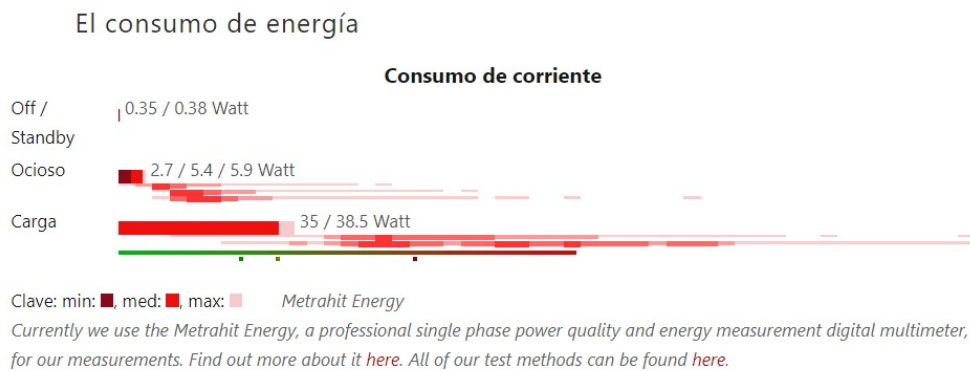
In the analysis of the power supply, it had already been seen that the power consumption of the components that are connected to it was 24V and 2.8A, which means a power consumption of 67.2W. Applying the efficiency formula used in this section, it is obtained a power input like the following one:

$$\text{INPUT POWER} = 67,2 / 0,87 = 77,24W$$

- **LAPTOP**

The laptop with which it is going to work will have a different consumption depending on the use it is given, and therefore the datasheet of the laptop will not show the efficiency of the energy it consumes.

Searching in several datasheets and official reports, no relevant data appears, but researching on the internet, it is possible to find the website [www.notebookcheck.org](http://www.notebookcheck.org), which performs complete analysis of computers, and is responsible for checking where the limits of each of these are. In the link <https://www.notebookcheck.org/El-Dynabook-Satellite-Pro-C50-E-en-review-Un-portatil-de-negocios-con-un-equipo-500202.0.html>, all the characteristics of the laptop that will be used for the rack are specified, including the consumption of the computer while it is charging or at rest:



**Figure 4.73** – Laptop efficiency

According to the study, the time when the laptop consumes the most power is when it is charging, consuming up to 38.5W. As this is the worst-case scenario, it will be used to calculate the total power consumption of the rack.

A table can now be made showing the consumption of each of the parts, and the sum total of all parts:

MODULE	POWER (W)
EGSE BOARDS POWER SUPPLIES	216,68
UUTS POWER SUPPLIES	157,84
DIN-RAIL POWER SUPPLY	77,24
LAPTOP	38,50
<b>TOTAL</b>	<b>490,26</b>

The total consumption of the rack will be 490.26 W, and, taking into account that the Spanish electricity grid works with 220V voltage, the maximum current that the rack will consume can be obtained using the power formula, and, clearing the current and substituting, the following result is obtained:

$$\text{POWER} = \text{VOLTAGE} * \text{CURRENT} \rightarrow \text{CURRENT} = \text{POWER}/\text{VOLTAGE}$$

$$\text{CURRENT} = 490.26 / 220 = \mathbf{2.28A}$$

Once you know the power, current and voltage limits with which it is going to work, it will be necessary to look for the components that meet these requirements. As mentioned at the beginning, the design of the PPU will be based on previous projects, and therefore, in addition to the circuit breaker, differential switch and emergency stop button, which are the components included in the ADS® requirements, another differential switch will also be added to act as the main switch for the rack. These rack components will be installed on one of the DIN rails already purchased in the previous section.

### 4.2.6.1 CIRCUIT BREAKER

A circuit breaker is a device that cuts off the current of a circuit when it exceeds the limits of the circuit breaker. For this fundamental module of the rack, it will be trusted in the company **SCHNEIDER ELECTRIC**, which has already been seen in previous sections, and which has a large repertoire of different models. On the company's website, [www.se.com](http://www.se.com), looking in the **Thermomagnetic Circuit Breaker Protection** section, in the **Acti 9 iC60** category, you can filter by the latest generation of circuit breakers manufactured by the company. Then, the filters for the working conditions necessary for the rack are added, which will be, in terms of rated current value, the upper value closest to 2.28A; and in terms of the number of poles of the module, the value 2, as this device will be connected to the electrical grid.

Once all the filters have been applied, the list of circuit breakers is reduced to 9 elements, whose only differences are the current cut-off curves and the cut-off capacity. The **SCHNEIDER ELECTRIC** website explains the difference and the use given for each of the current cut-off curves:

#### Curvas de disparo

##### Curva B

- (equivalente a la antigua curva L: disparo entre 2,6 y 3,85 In):
- Protección de generadores, de personas y grandes longitudes de cable (en régimen TN e IT).
- Sobrecarga: térmico estándar.
- Cortocircuito: umbrales magnéticos fijados por curva B (Im entre 3 y 5 In o 3,2 y 4,8 In)

##### Curva C

- (equivalente a la antigua curva U: disparo entre 3,85 y 8,8 In):
- Protección de cables alimentando receptores clásicos.
- Sobrecarga: térmico estándar.
- Cortocircuito: umbrales magnéticos fijados por curva C (Im entre 5 y 10 In o 7 y 10 según los aparatos)

##### Curva D:

- Protección de cables alimentando receptores con fuertes puntas de arranque.
- Sobrecarga: térmico estándar.
- Cortocircuito: umbrales magnéticos fijados por curva D (Im entre 10 y 14 In)

##### Curva MA:

- Protección arranque de motores.
- Sobrecarga: no hay protección.
- Cortocircuito: umbrales magnéticos fijados por curva MA (Im fijado a 12 In)

##### Curva Z:

- Protección de circuitos electrónicos.
- Sobrecarga: térmico estándar.
- Cortocircuito: magnéticos fijados por curva Z (Im entre 2,4 y 3,6 In)

**Figure 4.74** – *Current cut-off curves types*

As can be seen in the image, the **Z cut-off** curve is the best for the protection of electronic circuits, and it is also the one that produces the cut-off earlier, activating at a current 2.4 times greater than the rated current. If this type of filtering is selected, only one model of circuit breaker remains:

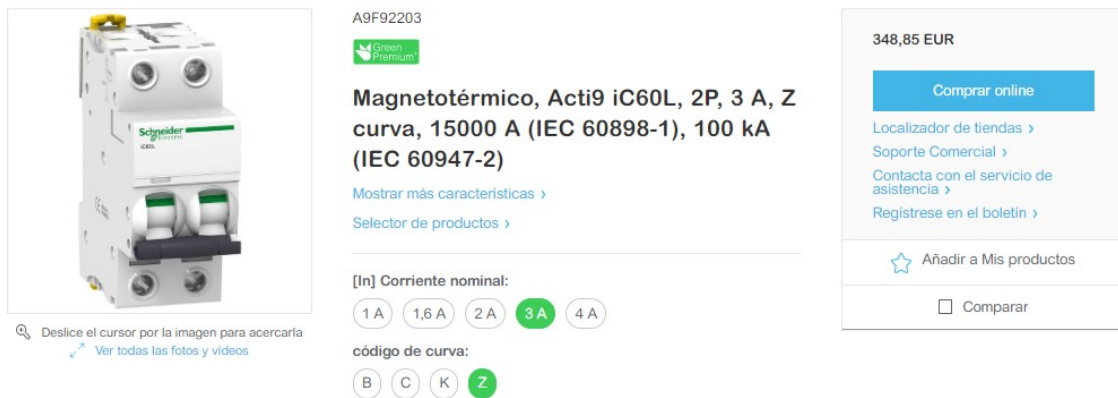


Figure 4.75 – A9F92203 model

The **A9F92203** model has a price of **348.85€** and meets all the requirements that had been calculated for the rack, having dimensions of 8.5 x 3.6 x 7.8 cm, and occupying a space of 3.6 cm on the DIN rail.

## 4

### 4.2.6.2 DIFFERENTIAL SWITCH

The differential switch is an element that is responsible for protecting the circuit from current leakage, such as, for example, the electrocution of a person. To choose this component, we will also use the calculations made in previous sections, and we will also work with the **SCHNEIDER ELECTRIC** company, but this time we will look in the **Acti9** differential protection section of the page, in the series of models for **iC60**.

In this section you can filter according to the needs of your rack as in the previous section. The first filter set will be the number of poles, which, as we have already seen, is 2. The rated currents available are 25A, 40A, and 63A. The rated current options are much higher than the current that will be used in the rack, so, rather than this characteristic, the first filter will be based on the sensitivity of the circuit breaker and then the one with the lowest rated current will be chosen.

According to Spanish standard **UNE 21302**, a residual current circuit breaker that guarantees adequate protection for people must have a sensitivity of less than or equal to 30mA, so, applying this filter to the list of circuit breakers, this is reduced to 15 models.

Next, you filter by the type of earth leakage differential switch you are looking for. The **SCHNEIDER ELECTRIC** website explains each of the types and their functionalities:

- **iLD Clase AC** : Estos equipos son aptos para protección de cargas estandar ( sin fuentes rectificadas ); detectan corrientes de fuga a tierra del tipo sinusoidal; brindan protección de personas contra riesgos de electrocución ( 30mA ), protección de instalaciones contra fallas de aislamiento y riesgo de incendio ( 300mA ); aplicables principalmente para industria y construcción. corriente nominal 25, 40, 63, 80A; version bipolar y tetrapolar

- **iLD Clase A** : Adecuados para instalar cuando hay receptores con dispositivos rectificadores ( diodos, tiristores etc ) en los que se pueda generar impulsos de corriente continua no detectados por dispositivos de clase AC. " brindan protección de personas contra contactos indirectos ( 30mA ),rotección de instalaciones contra fallas de aislamiento y riesgo de incendio ( 300mA ), corriente nominal 25, 40, 63, 80A; version bipolar y tetrapolar.

- **iLDsi Clase A " superinmunizados "** : Apto para cargas electrónicas que producen durante su funcionamiento, corrientes de fuga de alta frecuencia y/o fugas permanentes a frecuencia industrial de 60HZ, las cuales pueden generar disparos indeseados de los interruptores diferenciales clase AC, generando riesgo para las personas y problemas de continuidad de servicio.

Estos equipos son aplicados para instalarse en circuitos que alimentan :

- Computadoras, impresoras ó aparatos de oficina
- Iluminación fluorescente con balastos eléctricos
- Iluminación con variadores de intensidad ( dimmers )
- Variadores de velocidad electrónicos para motores.

Figure 4.76 – Differential switch classes

Class A is the one that matches the differential switch which is being searched for, as it is designed to work with corrective devices such as the power supplies used in the rack. Filtering by this class, the list is reduced to only two models

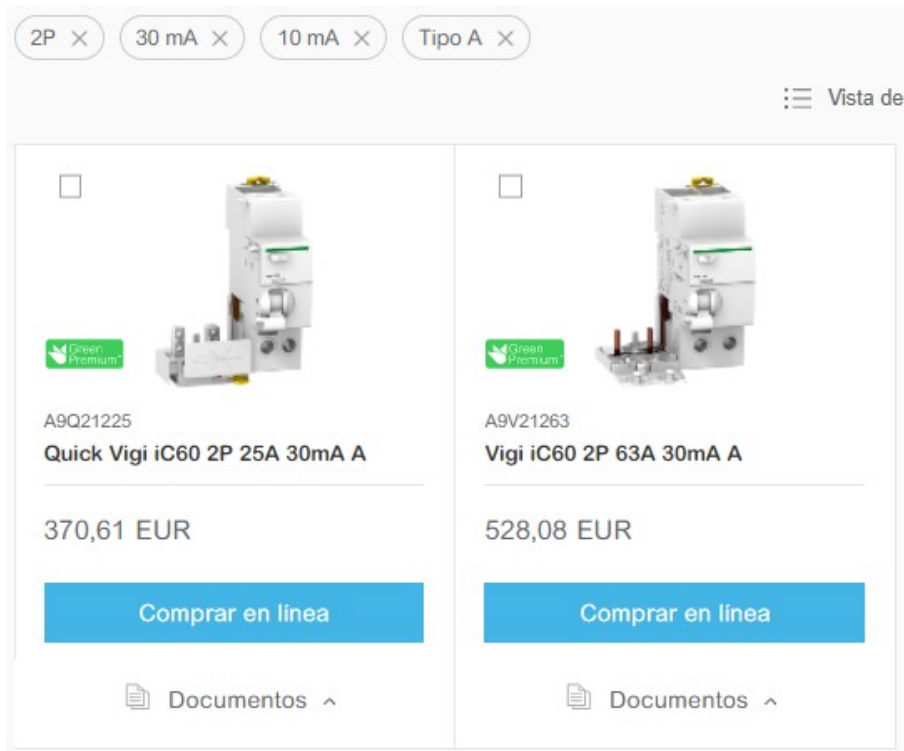


Figure 4.77 – Differential switch models

Of these two available models, the **A9Q21225** is the one with the lower rated current, which is also cheaper, with a price of **370.61€**, and dimensions of 9.1 x 2.7 x 7.3 cm, occupying a space of 2.7 cm on the DIN rail.



**Figure 4.78** – *A9Q21225 model*

## 4

### 4.2.6.3 EMERGENCY STOP BUTTON

The emergency button is an element that will manually cut off the power supply to the rack, in case it is necessary. This button does not have electrical characteristics that define it, as is the case with magneto-thermal and differential switches. The characteristics that can come to define it are colour, shape, space occupied, etc. For this purpose, for the rack, the same model of emergency stop button that has been used for other projects will be used, as it is a model with DIN rail fastening, and its dimensions, 4.7 x 4 x 8.2 cm, fit perfectly with those of the rack, occupying only 4 cm wide.

This model is the **XB4BT842** from **SCHNEIDER ELECTRIC**, and on the website, it is possible to find it for the price of **51,51€**.



**Figure 4.79** – *XB4BT842 emergency stop button model*

#### 4.2.6.4 RELAY

To enable the emergency stop button to work, a relay must be installed in the PPU to cut off the power supply to the rack. For this purpose, we will work again with the company **SCHNEIDER ELECTRIC**, with the **Acti 9** series relays, like the rest of the PPU components from this company. Filtering by the number of poles, which will be 2, and filtering by the models with the lowest amperage, which is 6, 3 models will be available:

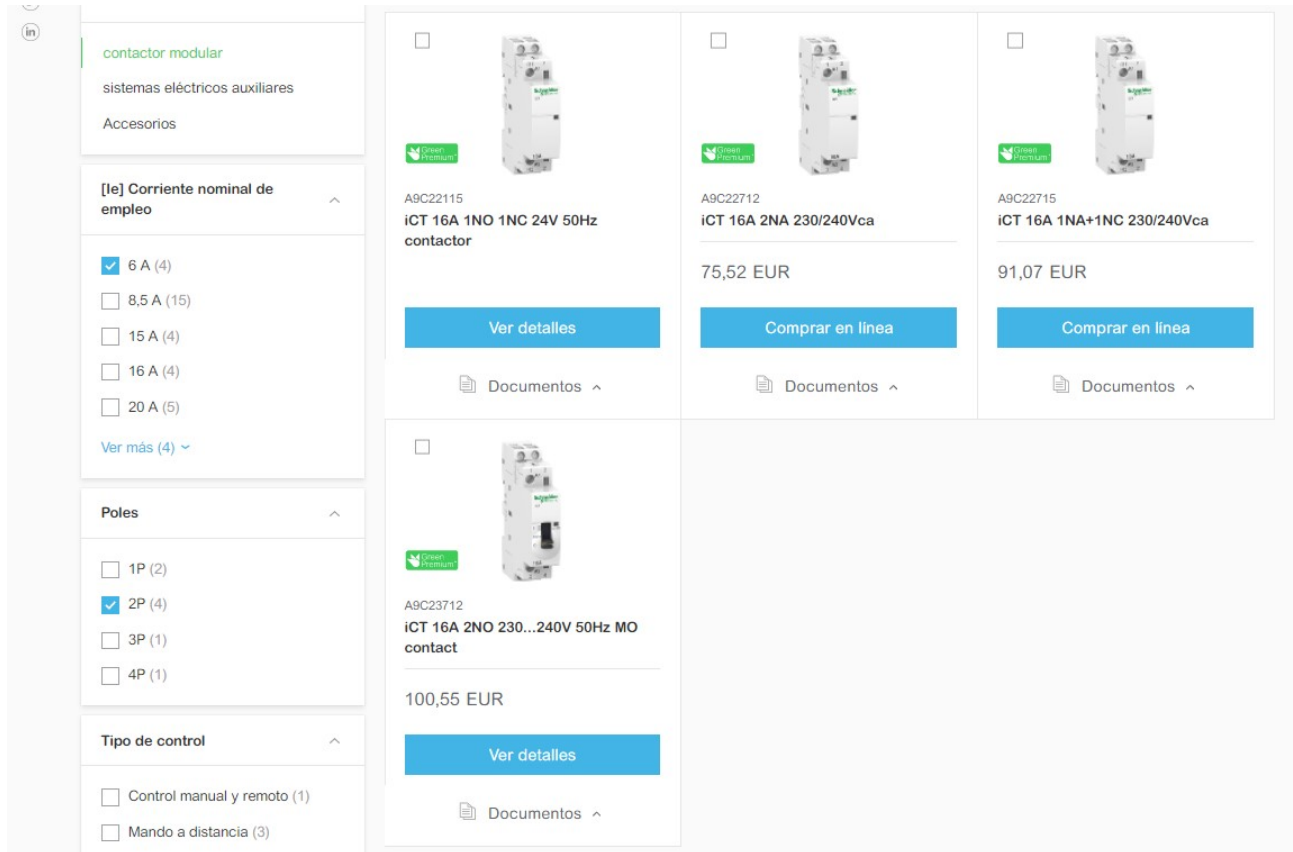


Figure 4.80 – Relay models on the website

Of these three models (the first one is the generic one and that is why the price is not shown), the first two are remote controllable, and the last one is manually controllable. As in this project, we want to control it by means of the mushroom pushbutton that has been selected in the previous section, we will choose between the first two models.



**Figure 4.81** – Relay models after filters

The only difference between these two models is the disposition of the two contact poles, in the first model, the **A9C22712**, the poles are both **NO**, normally open; while, in the second model, the **A9C22715**, one pole is **NO** and the other **NC**, normally closed.

4

The emergency stop button is **NO**, meaning that when it is not pressed, the circuit between the output and the input will be closed, and will open when pressed. As the normal state of this will be closed, it will be like a short circuit as long as it is not pressed.

In the relays, the state of the poles indicates how they work when they do not receive current, meaning that, if a relay has **NO** poles, the circuit will remain open until it receives current, when they will be closed. In the models to choose, when current circulates, and taking into account the poles of the emergency button, the poles of the first model will remain closed, thus making the current circulate through the system, however, in the second model one would remain closed but the other would remain open, so the whole system would not be closed and it would not work correctly.

This is why we chose the first model, the **A9C22712**, which has a price of **75.52€** and dimensions of 8.1 x 1.8 x 6.8 cm, occupying a space of 1.8cm on the DIN rail.




**Figure 4.82** – A9C22712 model



### 4.2.6.5 GENERAL SWITCH

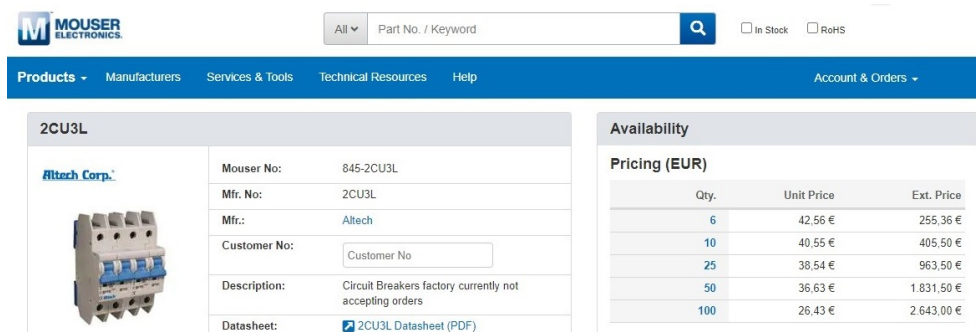
For this part of the PPU, a differential switch will be used as a general switch, meaning that it will be used to switch the whole rack on and off. As with the other elements of the PPU, the same element used in other racks will be chosen, but with the current corresponding to the consumption of this rack. For this purpose, we will work with the company **ALTERA TECH**. On their website <https://www.altechcorp.com>, in the breakers section, you can find a wide catalogue of **UL 489** series circuit breakers, where, looking at the models with C curve, and with two poles, you can choose the model according to the current it will support, that in this case will be 2.28A, and so the 3.0A model will be selected.



Rated Current	Type/ Cat. No.
0.2A	2CU02L
0.5A	2CU05L
1.0A	2CU1L
1.6A	2CU1.6L
2.0A	2CU2L
3.0A	2CU3L
4.0A	2CU4L
5.0A	2CU5L
6.0A	2CU6L
8.0A	2CU8L
10A	2CU10L
12A	2CU12L
13A	2CU13L
15A	2CU15L
16A	2CU16L
20A	2CU20L
25A	2CU25L
30A	2CU30L
32A	2CU32L
40A	2CU40L
50A	2CU50L
60A	2CU60L
63A	2CU63L

Figure 4.83 – 2CU3L model

The chosen model will be the 2CU3L, and it will have a shape like the one shown in the image above, with dimensions of 10.9 x 4.95 x 6 cm, occupying 4.95cm on the DIN rail. Looking for the indicated model on the **MOUSER ELECTRONICS** website, which is one of the official distributors of **ALTERA TECH**, the following price is obtained:




2CU3L		Availability																				
	Mouser No: 845-2CU3L Mfr. No: 2CU3L Mfr.: Altech Customer No: <input type="text" value="Customer No"/> Description: Circuit Breakers factory currently not accepting orders Datasheet: <a href="#">2CU3L Datasheet (PDF)</a>	<b>Pricing (EUR)</b> <table border="1"> <thead> <tr> <th>Qty.</th> <th>Unit Price</th> <th>Ext. Price</th> </tr> </thead> <tbody> <tr><td>6</td><td>42,56 €</td><td>255,36 €</td></tr> <tr><td>10</td><td>40,55 €</td><td>405,50 €</td></tr> <tr><td>25</td><td>38,54 €</td><td>963,50 €</td></tr> <tr><td>50</td><td>36,63 €</td><td>1.831,50 €</td></tr> <tr><td>100</td><td>26,43 €</td><td>2.643,00 €</td></tr> </tbody> </table>			Qty.	Unit Price	Ext. Price	6	42,56 €	255,36 €	10	40,55 €	405,50 €	25	38,54 €	963,50 €	50	36,63 €	1.831,50 €	100	26,43 €	2.643,00 €
Qty.	Unit Price	Ext. Price																				
6	42,56 €	255,36 €																				
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25	38,54 €	963,50 €																				
50	36,63 €	1.831,50 €																				
100	26,43 €	2.643,00 €																				

Figure 4.84 – 2CU3L price

The switch will come in packs of 6 units with a total price of € 255.36, meaning an individual cost of **42.56€** per switch.



The sum of the space occupied on the DIN rail by the components gives the following calculations:

<b>MODULE</b>	<b>SPACE OCCUPIED (cm)</b>
<b>CIRCUIT BREAKER</b>	3.6
<b>DIFFERENTIAL SWITCH</b>	2.7
<b>EMERGENCY STOP BUTTON</b>	4
<b>RELAY</b>	1.8
<b>GENERAL SWITCH</b>	4.95
<b>TOTAL</b>	<b>17.05</b>

The DIN rail must have a length equal to the width of the rack, therefore, as this is a standardised measurement and is 19", the length of the DIN rail will be 48.26cm, giving plenty of space for all the elements to be installed without disturbing each other. This means that it is only necessary to buy a 19" DIN rail to fit these elements.

The height that this rail will occupy will be given by the maximum height of its components, which, being in a vertical position, will be as follows:

<b>MODULE</b>	<b>HEIGHT (cm)</b>
<b>CIRCUIT BREAKER</b>	8.5
<b>DIFFERENTIAL SWITCH</b>	8.2
<b>EMERGENCY STOP BUTTON</b>	4.7
<b>RELAY</b>	8.1
<b>GENERAL SWITCH</b>	10.9
<b>MAXIMUM</b>	<b>10.9</b>

The DIN rail will then have a height of 10.9cm, which is 4.29 inches, and when converted to rack height units, this would be about **3U**.

### 4.2.7 POWER STRIP

Once you have finished choosing all the components that will consume power from the rack, you can move on to choosing the size of the power strip to be used. Of all the components in the rack, the ones that consume power directly from the electrical grid are the ones listed in the PPU design section, which are:

- EGSE BOARDS POWER SUPPLIES
- UUTs POWER SUPPLIES
- DIN-RAIL POWER SUPPLY
- LAPTOP


Not all the items listed need the same number of sockets, so a table is made to list how many will be needed:

ITEM	SOCKETS
EGSE BOARDS POWER SUPPLIES	1
UUTS POWER SUPPLIES	3
DIN-RAIL POWER SUPPLY	1
LAPTOP	1
<b>TOTAL</b>	<b>6</b>



As the number of sockets required is less than 7, the power strip selected for other projects, which has a space of 7 sockets, can be used. This power strip is model **DK 7240220** from the company **RITTAL**, with easy installation in a 19' rack occupying 1U in height, and its price on the internet is as follows:


Rittal DK 7240.220 Socket strip 7x, with switch 1 pc(s)



Item no.: 524370  
 Manufacturer no.: 7240.220  
 EAN: 2050000165610

Socket strip, 7 sockets and switch  
[Full description](#)

Warranty: 24 months  
 Manufacturer: Rittal



Available 67 pieces  
 Ready for dispatch: Thu 5.8.

**70,99 €** VAT incl.

59,16 € VAT excl.

1 piece	70,99 €
5+ pieces	68,86 €
10+ pieces	67,44 €
50+ pieces	63,89 €
100+ pieces	56,79 €

- 1 + Add to Cart

**Figure 4.85** – *DK 7240220 price*

### 4.2.8 RACK SIZE

Now that the number of modules needed to make the rack work is known, the most important thing to know is the final size of the rack. Counting the height occupied by each of the components of the rack, we obtain the following:

- EIM BOX: **5U**
- UUTs POWER SUPPLIES: **3U**
- DIN-RAIL: **4U**
- PPU: **3U**
- POWER STRIP: **1U**

As the DIN rail and the PPU will have almost no depth, both will be placed at the same height, one at the back and one at the front, so that, between them, they will only occupy 4U instead of 7U. After this, adding all the heights together, a total of **13U** is obtained.

The company has two models of racks depending on the number of units that will be needed, a large **42U**, for projects that have the computer integrated in the rack, and need much more space, and another **15U**, which is used for projects with more compact racks and that are manageable from laptops. As 13U will be needed for this project, it is possible to use without problem the **15U** model that is normally used in the company, which is the model **SMA20024** of the company **VERTIV**, and which has external dimensions of 74.5 x 60 x 80 cm, has a glass door, and connections of the modules by means of hole extrusion. This model is available on [www.sig.es](http://www.sig.es), and the price of it can be consulted by calling 918898961:



Figure 4.86 – SMA20024 price

By calling the number mentioned above, a price of **747,84€** is offered.

### 4.3 EGSE diagram

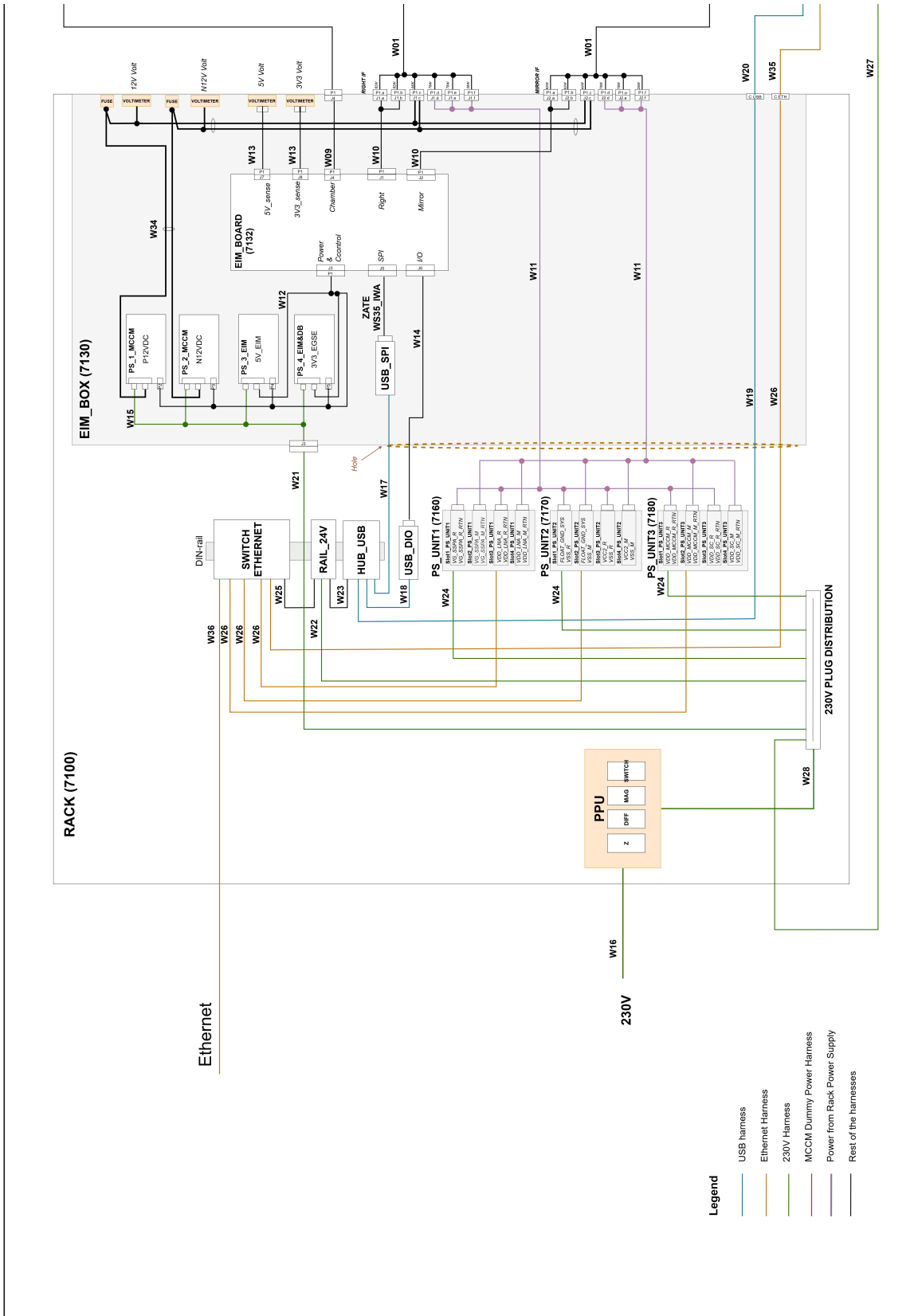
Now that all the modules needed to run the rack have been chosen, a diagram can be drawn showing which modules there are, and the cables that will be used to connect them.

This diagram, that is shown on the next page, shows the different connections made between the rack modules and the UUTs. It can be seen how the 230V electrical socket enters from the outside, and when it passes through the PPU, it arrives at the power strip, from which the different components that require the electrical socket are plugged in, and which distribute the power obtained through them. The internet connection can be seen to be made via an Ethernet cable, which arrives at the Ethernet switch, which is responsible for switching internet connections and communications between different devices.

Regarding the EIM BOX, it can be seen how the power is distributed from the socket to the internal power supplies, and from there, to the EGSE boards. The internal power supplies will be passed through voltmeters to check that the voltage they are delivering is correct, and the 12V supplies will be passed through a fuse for extra precaution. The voltmeters and fuses will be selected from the company's in-house stock, and will be explained in the section on the front-end design of the EIM BOX.

All signals to be transmitted to the UUTs, both power and control signals, will be transmitted from the EIM BOX through a cable, the W01. This cable must be connected to the front of the EIM BOX, which will be the physical interface that allows the connection to the rack. For the design of this front panel, first we will have to know the connectors that W01 will have, and then the aluminium front panel of the EIM BOX will be mechanised, distributing the space as it is most convenient. This part of the design will be the final one, as first we will have to design the necessary cables for the connection of the rack modules. Then, in the part of the UUTs, it is possible to see the connections between the boards through different cables and interfaces that have already been explained before.

4



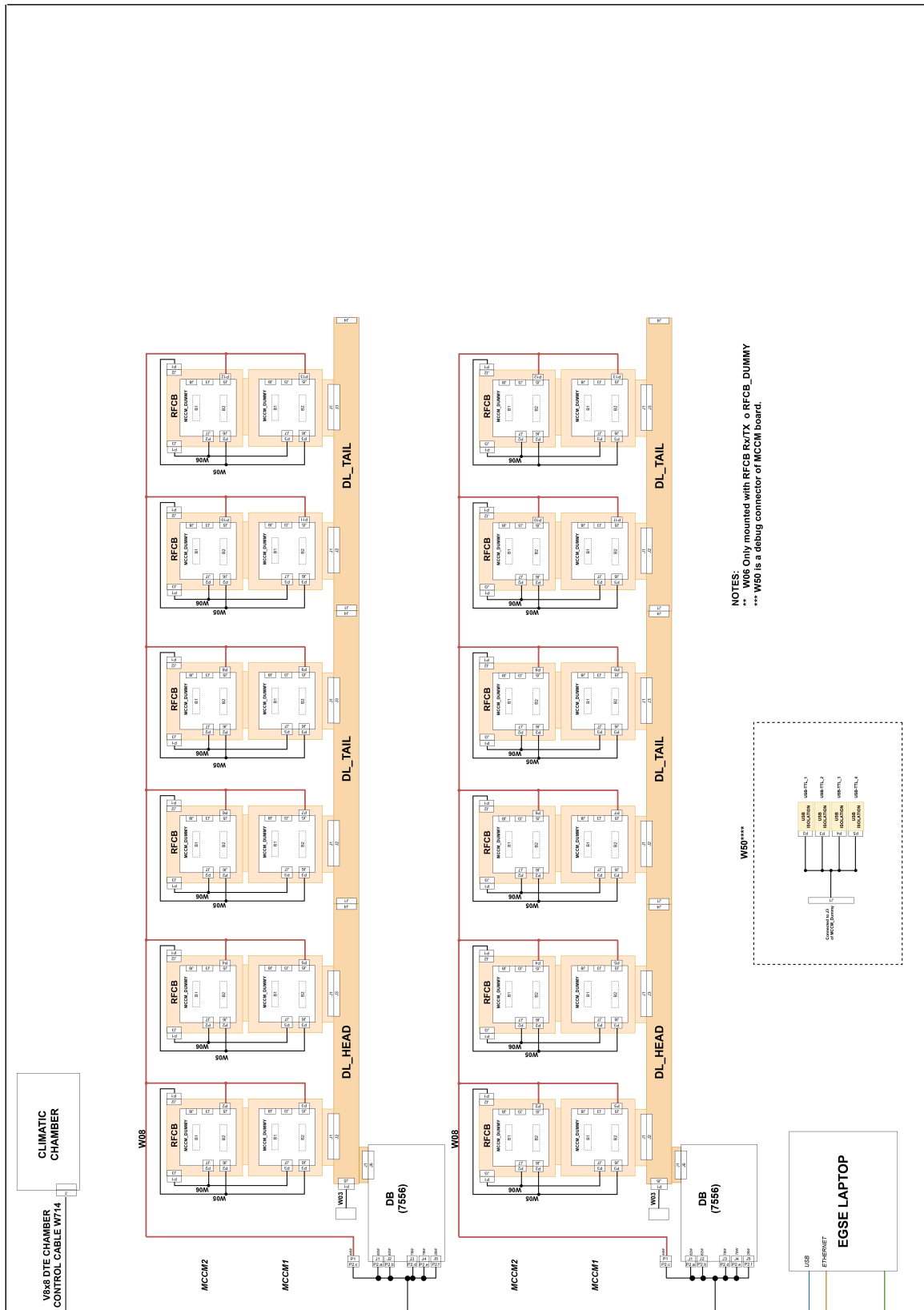


Figure 4.87 – EGSE diagram

## 4.4 EGSE CABLES

These cables are the ones that will be used to connect the different parts of the EGSE, and will be all the ones that can be seen in the diagram above. They can be classified into two main groups: **COTS** and **TBT**. **COTS** cables, or Commercial Off-The-Shelf, are cables that are purchased from suppliers, as they are cables already on the market, such as an Ethernet cable. [Tecnobit-Grupo Oesia](#)'s cables, **TBT**, are the ones that have to be manufactured by hand at the company, due to the complexity of these cables.

An example for better understanding would be a VGA cable, the typical cable that was connected from the computer to a projector or screen to reproduce on this one the same as on the computer. These cables are pin-to-pin cables, at each terminal they had a 15-pin connector, in which pin 1 of connector A corresponds to pin 1 of connector B, as well as all the pins of the connectors. But if you wanted to get the information from this cable on three connectors with fewer pins to make a separate analysis of the integrity of the signals, for example, pin 1 of connector A would not have to correspond to pin 1 of connector B, C, or D. Then, all **COTS** and **TBT** cables will be explained by dividing them into two sections.

### 4.4.1 COTS

These cables will be those bought from external companies, and whose price is cheaper to buy from outside than to manufacture them inside the company. The EGSE's COTS cables will be as follows:

- W14
- W16
- W17
- W18
- W19
- W20
- W21
- W22
- W23
- W24
- W25
- W26
- W27
- W28
- W35
- W36



#### 4.4.1.1 W14

This cable will connect the USB-DIOs to the J6 interface of the EIM BOARD. Checking the EIM BOARD and USB-DIOs sections, you can see that the connection interfaces are the same, and therefore the cable will be a pin-to-pin cable. This cable is available from the NI shop, for a price of **231€**, and will be one metre long:



**Figure 4.88** – *W14 cable*

#### 4.4.1.2 W16

This cable will simply be a cable with a SCHUKO male connector at one extreme and stripped wires at the other end for plugging into the PPU. In chapter 3, the requirements, it is specified that one of the requirements is that the rack must be connected to the socket through a connector that complies with **IEC 60309**. As it is not very common to find cables with such a connector at one extreme and stripped wire at the other end, a cable with the connector that is being searched for at one extreme will be purchased and the wires will be cut and stripped by hand.

On the internet, it is possible to find through the German distributor **THOMANN**, a cable whose ends are both **IEC 60309** compliant connectors, but one is male and the other is female.



**Figure 4.89** – *W16 cable*

This cable can withstand up to 16A of current, which is much more than needed by the rack, and is 5m long, which would be enough to keep the rack plugged in, even if it is far away from the socket. The price would be 18,90€ plus 15€ shipping, making a total of **33,90€** for this one.

#### 4.4.1.3 W17

This cable will connect the HUB USB to the USB-SPI located inside the EIM BOX. On the HUB USB, all the connection ports will be USB Type A 3.0 female ports, so one end of the W17 will be a USB Type A male. Regarding the USB-SPI, the connector that does not go to the EIM BOARD is a USB Type B 2.0 female connector, so the other end of the W17 cable will have to be a USB Type B 2.0 male connector. As the end connected to the USB-SPI is USB Type B 2.0, the other connector will also have to be 2.0.

At **RS Components** website it is possible to find such a cable with a price of **2,19€**.

#### Cable USB USB 2.0, 0.8m, Blanco, USB A macho a USB B macho



Código RS: 182-8864 | Fabricante: RS PRO



48 Entrega en 24 horas

2288 Disponible para entrega en 24/48 horas

Precio Unidad

**1,81 €**  
(exc. IVA)

**2,19 €**  
(inc. IVA)

unidades	Por unidad
1 +	1,81 €

- 1 + unidades

**Añadir**

Disponibilidad de stock

Figure 4.90 – W17 cable

With a price of only 2,19€ and a length of 0.8m, that will be more than enough to connect the HUB USB with the USB-SPI without any problem.

#### 4.4.1.4 W18

This cable connects the USB-DIOs to the HUB USB. This is included with the USB-DIOs, and is already connected to it, having a USB Type A 2.0 cable on the other side, so there would be no problem connecting it to the HUB USB.

4.4.1.5 W19

To connect the HUB USB to the computer, it will be necessary to first go through the front of the EIM BOX, which is the interface between the inside of the rack and the UUTs and the computer. For that reason, what would be a USB type A pin to pin cable is divided into two, the **W19** cable and the **W20** cable, which will be connected through a connector on the front of the EIM BOX.

The connector that will be used for this rack will be the same as the one used for other projects, which is a panel mount connector, and has a USB Type A 2.0 female port on one end, and a USB Type B 2.0 female port on the other end. It is available from **RS Component** and is priced at **20.19€**.

**Conector USB Bulgin PX0842/B, Hembra, Recta IP68, Montaje en Panel, Versión 2.0, 30,0 V., 1.0A, Buccaneer**



Código RS: 468-6327 | Nº ref. fabric.: PX0842/B | Fabricante: Bulgin

25 Entrega en 24 horas  
1179 Disponible para entrega en 24/48 horas

Precio Unidad  
**16,69 €**  
(exc. IVA)      **20,19 €**  
(inc. IVA)

- 1 + unidades

Añadir

Figure 4.91 – USB front panel connector

As can be seen in the image above, the back of the connector, the one inside the EIM BOX, is the extreme with a USB Type A 2.0 female connector, so the **W19** cable will be a pin-to-pin USB Type A 2.0 male cable.

Such a cable can be found at **RS Component** at a good price and with a length of 1.8m, which is enough to connect the HUB USB to the front connector, and is priced at **4,25€**.



**Cable USB USB 2.0, 1.8m, Negro, Male USB A a Male USB A**

Código RS: 182-8546 | Fabricante: RS PRO



**65 Entrega en 24 horas**  
38 Disponible para entrega en 24/48 horas

Precio Unidad  
**3,51 €**  
(exc. IVA) **4,25 €**  
(inc. IVA)

unidades	Por unidad
1 +	3,51 €

unidades

Figure 4.92 – W19 cable

4.4.1.6 W20

This cable will be the one that connects the above-mentioned connector to the computer. As it has been seen, the front side of the connector is a USB Type B 2.0 female, so the end of this cable will be a USB Type B 2.0 male. The other side, as it will be connected to the computer, will be a USB Type A 2.0 male connector.

Searching through the filters on the **RS Component** website, it is possible to find a multitude of cables. Among them all, there is one that can be seen in the following photo, which is 2m long, which would allow us to move the computer with the certainty that it will not disconnect from the rack, and its price is only **4.02€**.

**Cable USB USB 2.0, 2m, Gris, Male USB A a Male USB B**

Código RS: 182-8832 | Fabricante: RS PRO



**32 Entrega en 24 horas**  
6288 Disponible para entrega en 24/48 horas

Precio Unidad  
**3,32 €**  
(exc. IVA) **4,02 €**  
(inc. IVA)

unidades	Por unidad
1 +	3,32 €

unidades

Disponibilidad de stock

Figure 4.93 – W20 cable

4.4.1.7 W21

The W21 will be the cable through which the current will circulate to the power supplies inside the EIM BOX. Once inside the EIM BOX, the current will be distributed through another cable, the W15, which will have five ends, four to supply each of the sources, and one which will be a panel mounting socket with a switch that will be located on the front of the EIM BOX, and through which the W15 will be connected to the W21.

This panel mount socket will be chosen later during the design of the W15. However, this type of socket always has an input terminal in the form of a rectangular male SCHUKO plug, or technically speaking a male C13 connector. So one terminal of the W21 will have the shape of a C13 female connector, and the other terminal, as it is connected to the power strip, will have to have a normal SCHUKO plug, or technically speaking an F-type plug.

At RS Component there are many different models of power cables, and by filtering for the needs mentioned above, it is possible to find a cable with a length of 2m, which is perfectly adapted to the needs, and has the necessary length to be able to go from the power strip to the front without the need for the cable to be taut. The price of this cable is 17,22€, and it is like the one in the following image.

**Cable de alimentación RS PRO de 2m, de color Negro, conect. A C13, IEC, conect. B CEE 7/7, Schuko, Libre de halógenos y**



Código RS: 123-0958 | Fabricante: RS PRO

Precio Unidad	
<b>14,23 €</b> <small>(exc. IVA)</small>	<b>17,22 €</b> <small>(inc. IVA)</small>
unidades	Por unidad
1 - 9	14,23 €
10 - 24	13,23 €
25 +	12,52 €

unidades

Figure 4.94 – W21 cable

4.4.1.8 W22

This cable will be responsible for supplying power to the 24V source on the DIN rail. At one end it will have a male F-type connector, as it will be plugged into a power strip, and at the other extreme it will go to the power supply.

In the datasheet of the 24V power supply it is possible to see that the input and output connection is made by screw terminals, with cable that can go from AWG22 to AWG12:



Connections - terminals

Screw type terminals for input connection, connection capacity: 3 x 0.5...3 x 4 mm<sup>2</sup> AWG 22...AWG 12  
 Screw type terminals for input ground connection, connection capacity: 1 x 0.5...1 x 4 mm<sup>2</sup> AWG 22...AWG 12  
 Screw type terminals for output connection, connection capacity: 4 x 0.5...4 x 4 mm<sup>2</sup> AWG 22...AWG 12  
 Screw type terminals for output ground connection, connection capacity: 1 x 0.5...1 x 4 mm<sup>2</sup> AWG 22...AWG 12

Figure 4.95 – 24V power supply datasheet

As the connection type is screw terminals, the end of the W22 cable will be stripped wires with an AWG thickness between **AWG22** and **AWG12**.

Searching on the **RS Component** website it is possible to find a cable with the characteristics of both ends as the ones required, with a length of 2m and with a price of 9,08€.

Cable de alimentación RS PRO de 2m, de color Negro, conect. A Unterminated, conect. B CEE 7/3, Schuko, 250 V / 10 A,



Código RS: 490-239 | Fabricante: RS PRO

Precio Unidad	
7,50 €	9,08 €
(exc. IVA)	(inc. IVA)
unidades	Por unidad
1 - 9	7,50 €
10 - 24	7,22 €
25 - 49	6,92 €
50 +	6,61 €

1 unidades

Añadir

Figure 4.96 – W22 cable

To see if it is thick enough to fit into the terminals of the power supply, the datasheet is analysed and the cross-section of the inner cable is checked.

Especificaciones mecánicas	
Longitud	2m
Área de sección transversal	0.75mm <sup>2</sup>
Peso	175g
Fuerza de retirada	10N-50N
Relativo	1,5 mm <sup>2</sup>
Transferencia de hilo de cobre	48 filamentos de 0,202 mm <sup>2</sup>

Figure 4.97 – W22 seccion

The inner cable will have a cross-section of 0.75mm<sup>2</sup>, which, looking at the AWG to mm<sup>2</sup> conversion tables, corresponds to a measurement between **AWG 19** and **AWG 18**:

AWG	Ø mm	Area mm <sup>2</sup>	AWG	Ø mm mm	Area mm <sup>2</sup>
1	7.35	42.40	16	1.29	1.31
2	6.54	33.60	17	1.15	1.04
3	5.86	27.00	18	1.024	0.823
4	5.19	21.20	19	0.912	0.653
5	4.62	16.80	20	0.812	0.519
6	4.11	13.30	21	0.723	0.412
7	3.67	10.60	22	0.644	0.325
8	3.26	8.35	23	0.573	0.259
9	2.91	6.62	24	0.511	0.205
10	2.59	5.27	25	0.455	0.163
11	2.30	4.15	26	0.405	0.128
12	2.05	3.31	27	0.361	0.102
13	1.83	2.63	28	0.321	0.0804
14	1.63	2.08	29	0.286	0.0646
15	1.45	1.65	30	0.255	0.0503

Figure 4.98 – AWG table



Therefore, the cable that is available in **RS Component** is valid for use as W22.

4.4.1.9 W23

This cable will be in charge of powering the HUB-USB, which has jackscrews as input terminals. As we have seen before, the 24V supply also has output jackscrews terminals, and therefore, this cable will simply be a conductor wire that will connect the output terminals of one module with the input terminals of the other.

Analysing the datasheet for the thickness required for the HUB-USB input terminals, it can be seen that two wires for this terminal are included in the box. So, since the 24V power supply and the HUB-USB will be located next to each other, these two wires will be used as W23 cables.

What's in the Box	Included in Package	
		1 - 7 Port Industrial USB 3.0 Hub
		1 - USB 3.0 A - B Cable
		1 - DIN Rail Mounting Kit
		1 - Terminal Block (2 Wire)
		1 - Instruction Manual

Figure 4.99 – HUB-USB datasheet

#### 4.4.1.10 W24

The W24 cable will be the one that supplies power to each of the UUTs' power supplies. These power supplies have a **C13** plug as a power connector. Therefore, these three cables that will be in charge of powering the three power supply modules will be the same as the W21.

The difference between the W24 and the W21 is that the three W24 cables are included in the power supply boxes, so there is no additional cost.

#### 4.4.1.11 W25

This cable will connect the SWITCH ETHERNET to the 24V supply on the DIN rail, and as with the HUB USB, the input terminals of the SWITCH ETHERNET will be jackscrew terminals.

In the datasheet it is not indicated if there are cables included in the box as in the case of the W23, and therefore, this time they will be purchased. As previously indicated, this cable will have stripped wires at both ends, and therefore it will only be necessary to buy a single AWG wire that allows connection to both modules.

In the case of the SWITCH ETHERNET, it does not indicate the wire that allows the input terminals, but as in the 24V supply it indicates that it has to be between **AWG 16** and **AWG22**, copper wire of **AWG22** will be selected, which is the thinner wire that the 24V supply accepts, and it is also the one that is usually used for power transmission. Remember that on the AWG scale, the higher the number, the smaller the wire thickness.

As **AWG22** copper wire will be used during the design of the cables, and the W25 will be a short cable, instead of buying copper wire for this cable, the price will be calculated once all the cables have been designed, and it will be possible to know how many metres of **AWG22** will be used.

#### 4.4.1.12 W26 / W35 / W36

All these cables are going to be the same, the difference in their nomenclature is the connection points between them.

The W26, will be the cable that will be in charge of connecting the SWITCH ETHERNET with the sources of the UUTs. Like all ETHERNET cables, this cable will be a pin-to-pin cable with an **RJ45** connector at both ends.

As with the USB cable, the computer in charge of the tests must also have a connection via ETHERNET with the external network and with the modules that can be controlled by this way. For this purpose, an ETHERNET panel connector will have to be selected to serve as an interface between the ETHERNET cable coming out of the computer and the one



coming out of the SWITCH ETHERNET, meaning between the W26 and the W35 cable.

In the same way that the USB connector was chosen for the panel, looking on the RS Component page, it is possible to find a connector similar to the one selected for the W19 cable, but with a female **RJ45** input and output connector, and with a price of **53.69€**.

**Conector RJ45 Bulgin PX0833, Vías: 8, Cat5e, Cat6a, Apantallado, Recto, Montaje en Panel, Hembra 1, Serie Buccaneer**

Código RS: 468-6232 | Nº ref. fabric.: PX0833 | Fabricante: Bulgin



**41 Entrega en 24 horas**

5395 Disponible para entrega en 24/48 horas

Precio Unidad

44,37 €

(exc. IVA)

53,69 €

(inc. IVA)

unidades	Por unidad
1 - 14	44,37 €
15 - 49	41,75 €

- 1 + unidades

Añadir

Disponibilidad de stock

**Figure 4.100** – *ETHERNET front panel connector*

As both ends of the panel connector are **RJ45** female, the connectors that fit into this of the W26 and W35 cable will be **RJ45** male.

The W35, which connects the front panel connector to the laptop, will also be a pin-to-pin cable with both ends having **RJ45** male connectors.

The W36, is the cable that will connect the SWITCH ETHERNET, and therefore the whole rack, to the external internet network. Logically, this cable will also be the same as the W26 and W35.

Therefore, 4 W26 cables, 1 W35 cable, and 1 W36 cable will be needed. This makes a total of 6 ETHERNET cables, which can be found on the **RS Component** website with high performance for the following price.



## Cable de Cat6 HellermannTyton 851-16320 RJ45SPC6-03.0M/WH (3.0), Blanco, LSZH RJ45 macho/RJ45 macho, 3m



Código RS: 903-4465 | N° ref. fabric.: 851-16320 RJ45SPC6-03.0M/WH (3.0) | Fabricante: HellermannTyton



63 Disponible para entrega en 24/48 horas

Precio Unidad

**19,35 €**  
(exc. IVA)

**23,41 €**  
(inc. IVA)

unidades	Por unidad
1 - 9	19,35 €
10 - 49	18,39 €
50 +	17,42 €

- 4 + unidades

Añadir

Disponibilidad de stock

Figure 4.101 – W26 price

4

At a price of €23.41 each, that would be a total of **€140.46**.

### 4.4.1.13 W27

This cable is the one that will supply power to the computer, and it will be connected to the power strip inside the rack. Of course, this cable is included in the computer box, so you don't have to buy it.

### 4.4.1.14 W28

This is the cable that will connect the PPU to the power strip. For this cable, you will have to cut the cable that supplies power to the power strip, which is included in the power strip, and strip the wires so that they can be inserted into the switches of the PPU and so that they can carry out their protective function.

#### 4.4.2 TBT

The **TBT** cables will be those that are manufactured by hand in the company due to their complexity, either because of connectors with different pins at the ends, due to ramifications towards other modules or because there are no cables with these characteristics available on the market.

The process for designing these cables will be similar for all of them, although there may be differences from one to another. First of all, we will start by knowing what is being connected, so that, in this way, we will know where the connectors of the cable have to fit. Then, a drawing of these will be designed using the **Draftsight** tool from the company **Dassault Systèmes**. In this representation, the male connectors will be represented with the male contacts of the connector in black, and the female connectors with the contacts as circumferences. The small circles with numbers on the drawing will represent the item number by which each component is identified in the company's list of materials for each cable. Finally, the rectangles containing a pad and a number inside correspond to the label that has to be placed in that position.



Figure 4.102 – Draftsight logo

Once the measurements have been designed, the next step is to select the quantity of cable to be used, the protection it must have, and other complements that vary from one cable to another.

During this process, there will be two main types of connectors, and, in order not to be repetitive and explain the same thing several times, it will be explained what these types are, and how to find the connectors that are needed. The two main brands we will be working with are **NICOMATIC** and **HARTING**.

These two companies have already been discussed in the board section of the EGSE, so there is no need to introduce them.

To find the **NICOMATIC** connectors, first it is necessary to go into their official website, [www.nicomatic.com](http://www.nicomatic.com), and within their product offer, select the **HIGH PERFORMANCE MICRO-CONNECTORS** section, where it will be possible to select the type of connector that is more necessary.



Figure 4.103 – Nicomatic connector's series

In each of these sections, it is possible to choose the connector that is being searched for, progressively adding the filters that appear, until a serial number is created whose nomenclature is easy to understand. In this way, if we have a male connector, and we want to find a female connector that fits with it, we only have to change some of the numbers of the serial number to find the connector that fits with it.

4

Once you have the serial number, search the **NICOMATIC** shop, <https://www.nicomatic.store/>, for the connector to be found.

For **HARTING** connectors, look on the **RS Component** page <https://es.rs-online.com/web/c/conectores/usb-conectores-para-ordenadores-y-d-sub/conectores-d-sub/?applied-dimensions=4291690521,4291637516,4294391203,4294374343>, where the **HARTING** Sub-D connector filter is established, and where it is only necessary to filter by the number of pins and if it is male or female.

Regarding the conductor wire, as already mentioned in the previous section, for each cable, we will say approximately how many metres are going to be used, and at the end, it will be added up all the metres of each of the thicknesses that exist. As the conductor that will be used is very commonly used in the company, as cables are a fundamental part of any system; when ordering the quantity of conductor to be used, the necessary metres will be requested from the warehouse through **SAP**. Where, for example, each of the conductors has the following price per metre.

006ETS40001	CABLE TEFLON FLEXIBLE BLANCO AWG24 CuAg	0,220 mm2	AWG24	0,36
006ETS40002	CABLE TEFLON FLEXIBLE BLANCO AWG20 CuAg	0,600 mm2	AWG20	0,87
006ETS40003	CABLE TEFLON FLEXIBLE BLANCO AWG20 CuAg	0,600 mm2	AWG20	1,53
006ETS40004	CABLE TEFLON FLEXIBLE BLANCO AWG18 CuAg	0,930 mm2	AWG18	1,34
006ETS40005	CABLE TEFLON FLEXIBLE BLANCO AWG22 CuAg	0,340 mm2	AWG22	0,74
006ETS40011	CABLE TEFLON RIGIDO BLANCO AWG24 CuAg	0,200 mm2	AWG24	0,06
006ETS40013	CABLE 2 AISL. FLEXIBLE BLANCO AWG24 CuSn		AWG24	1,86
006ETS40014	CABLE ETFE FLEXIBLE BLANCO AWG22 CuSn	0,380 mm2	AWG22	0,22
006ETS40019	CABLE ETFE FLEXIBLE BLANCO AWG24 CuSn	0,250 mm2	AWG24	0,15
006ETS40027	CABLE TEFLON FLEXIBLE NEGRO AWG22 CuAg	0,338 mm2	AWG22	1,73
006ETS40030	CABLE TEFLON FLEXIBLE NEGRO AWG20 CuAg		AWG20	0,92
006ETS40210	CABLE PTFE FLEXIBLE BLANCO AWG26 CuAg		AWG26	0,50
006ETS40032	CABLE PVC FLEXIBLE AMAR./VERDE AWG22 Cu		AWG22	0,72
006ETS40033	CABLE TEFLON FLEXIBLE BLANCO AWG14 CuAg	1,910 mm2	AWG14	3,26
006ETS40034	CABLE TEFLON FLEXIBLE BLANCO AWG16 CuAg	1,340 mm2	AWG16	1,65

Figure 4.104 – Conductors prices

All the cables to be used in the project will be flexible, meaning that there will not be a single conductor core, but multiple thin copper wires that will allow the conductor to be non-rigid. In most cases, the insulation will be white Teflon, as Teflon is a flexible material with a melting point of 350°, which makes it possible to work with soldering irons without melting the insulation covering the wire.

Depending on the type of signal the conductor is carrying, a wire of one width or another will be chosen. If the signals to be transported are communications signals, thinner wires are usually used, meaning, with a higher AWG value, such as **AWG 24** and **AWG 26**. For wires that transmit power, however, thicker wires are usually chosen, normally **AWG 22**, as the current is divided between several wires, and if all the power is going to be transmitted through one or two wires, **AWG 16** or **AWG 14**.

Once you have the connectors and the amount of wire needed, depending on the cable, it will be chosen a coating that allows keeping all the wires together along the entire length of the cable. Also, a label will be found to identify the ends of each cable, and the cable number it is.

The coating, if it has one, will always be polyester braided sleeve, which has the advantage that it is flexible and has a wide range of diameters, since, depending on how closed the sleeve is, it will have a larger or smaller diameter. The labels, however, will be retractable, meaning that they will have an initial diameter, but once they are in position, they will be heated with hot air, and their diameter will decrease until they are adjusted to the total diameter of the cable.

As these nets and labels have different sizes, the models will have to be chosen according to the diameter of the cable. For this purpose, approximate calculations will be made for each of the cables, calculating the approximate area that the cable section will occupy, and extrapolating it to a larger circle that allows the approximate diameter of the sleeve or label

to be extracted. For this purpose, the following calculations must be made for each of the cables.

First, it is necessary to know the area occupied by each wire, using the tables available in the wire's datasheet, according to its AWG:

Reference FILOTEX	CONDUCTOR				D.C. resist. at 20°C (Ohms/Km)	Overall diameter		Maximum weight  Kg / Km
	Gauge AWG	Cross section mm <sup>2</sup>	Construction n x Ø mm	Nom. Ø mm		maxi.	mini.	
					mm			
KZ 05 – 01	32	0,035	7 x 0.08	0.24	546	0.63	0.84	1.65
KZ 05 – 02	30	0,055	7 x 0.10	0.30	349	0.71	0.91	2.1
KZ 05 – 03	28	0,093	7 x 0.13	0.39	201	0.79	1.00	2.6
KZ 05 – 04	26	0,14	7 x 0.16	0.48	132	0.89	1.10	3.4
KZ 05 – 05	24	0,22	7 x 0.20	0.60	86	1.04	1.22	4.5
KZ 05 – 06	22	0,34	7 x 0.25	0.75	54.4	1.17	1.37	6.2
KZ 05 – 07	20	0,60	19 x 0.20	1.00	31.3	1.42	1.62	9.5
KZ 05 – 08	18	0,93	19 x 0.25	1.25	20.5	1.67	1.92	14.1
KZ 05 – 09	16	1,34	19 x 0.30	1.50	13.9	1.92	2.27	20.0
KZ 05 – 10	14	1,91	27 x 0.30	1.85	10.0	2.30	2.66	27.0
KZ 05 – 11	12	3,18	45 x 0.30	2.45	6.0	2.89	3.24	42.5

Figure 4.105 – AWG table for wires

The table shows the area of the conductor, but does not include the insulation protecting the conductor. Regarding the total diameter of the whole conductor, two columns are included which indicate the maximum and minimum diameter that it can have. For this reason, in order to make the corresponding calculations, a new table will be created with the average values of the maximum and minimum diameter:

AWG \ DIAMETER	MINIMUM	MAXIMUM	OVERALL	RADIUS
<b>32</b>	0.63	0.84	<b>0.74</b>	<b>0.37</b>
<b>30</b>	0.71	0.91	<b>0.81</b>	<b>0.41</b>
<b>28</b>	0.79	1.00	<b>0.90</b>	<b>0.45</b>
<b>26</b>	0.89	1.10	<b>1.00</b>	<b>0.50</b>
<b>24</b>	1.04	1.22	<b>1.13</b>	<b>0.57</b>
<b>22</b>	1.17	1.37	<b>1.27</b>	<b>0.64</b>
<b>20</b>	1.42	1.62	<b>1.52</b>	<b>0.76</b>
<b>18</b>	1.67	1.92	<b>1.80</b>	<b>0.90</b>
<b>16</b>	1.92	2.27	<b>2.10</b>	<b>1.05</b>
<b>14</b>	2.3	2.66	<b>2.48</b>	<b>1.24</b>
<b>12</b>	2.89	3.24	<b>3.07</b>	<b>1.54</b>

Now, the area occupied by the entire wire must be calculated, using the radius obtained in the previous calculations. Once the radius is obtained, the area of the circle that contains the radius is calculated, and with this the approximate area occupied by the wire is obtained. For this purpose, the following formula is used:

$$\text{Wire's area} = \pi * \text{radius} * \text{radius}$$

Once the area of a wire is obtained, it is multiplied by the number of wires that the cable will have. If the cable is pin to pin, it will have as many wires as the number of pins in the connectors, but for these cables this will not always be the case. In this way, the approximate total area that the entire cable will occupy is obtained. It must be taken into account that this value is not going to be the exact value, since, as they are circular shapes, there will be air spaces between some wires and others, so the value obtained is the minimum space that the whole cable is going to occupy, and an approximate value of the total cross-section of its area.

$$\text{Cable's area} = \text{Wire's area} * n^{\circ} \text{ of conductors} = n^{\circ} \text{ of conductors} * \pi * \text{radius} * \text{radius}$$

Once the total area of the cable is known, the radius of the circle with the area obtained is calculated, and the diameter is obtained from this:

$$\text{Cable's area} = \pi * \text{Radius} * \text{Radius} = n^{\circ} \text{ of wires} * \pi * \text{radius} * \text{radius}$$

$$\text{Radius} = \sqrt{n^{\circ} \text{ of wires} * \text{radius} * \text{radius}}$$

With the total radius of the cable, a sleeve and a label can be chosen to cover the cable. The list of sleeves to work with will be the one shown in the following photo, which will be chosen according to the smallest and largest diameters of the sleeves:



General Purpose Alpha Part No. and Size	Flame Retardant Alpha Part No. and Size	Minimum Supplied I.D.		Maximum Expanded I.D.		Nominal Wall Thickness		Standard Put-Up Spools Ft.
		Inches	mm	Inches	mm	Inches	mm	
GRP-110-1/8	GRP-120-1/8	0.093	2,36	0.250	6,35	0.025	0,63	100, 500
GRP-110-1/4	GRP-120-1/4	0.125	3,18	0.437	11,09	0.025	0,63	100, 500
GRP-110-1/2	GRP-120-1/2	0.250	6,35	0.750	19,05	0.025	0,63	100, 500
GRP-110-3/4	GRP-120-3/4	0.500	12,70	1.250	31,75	0.025	0,63	100, 500
GRP-110-1-1/4	GRP-120-1-1/4	0.750	19,05	1.750	44,45	0.025	0,63	50, 250
GRP-110-1-3/4	GRP-120-1-3/4	1.250	31,75	2.750	69,85	0.025	0,63	50, 250
GRP-110-2	GRP-120-2	1.500	38,10	3.500	88,90	0.025	0,63	50, 250

Figure 4.106 – Braided sleeves models

As for the labels, they shall be chosen in the same way as the sleeves, but from the following list of retractable labels:

#### Available sizes and formats

Ordering description	Inside diameter				Recommended use range	Recovered wall thickness		Weight (g/10 pcs.)	
	Expanded D (minimum)		Recovered d (maximum)			mm	inches		
	mm	inches	mm	inches					
TMS-SCE-1K- <sup>3</sup> / <sub>32</sub> -2.0- <color>	2.36	0.093	0.79	0.031	0.81 - 1.90	0.032 - 0.075	0.53 ± 0.08	0.021 ± 0.003	1.50
TMS-SCE-2X-1K- <sup>3</sup> / <sub>32</sub> - <color>	2.36	0.093	1.17	0.046	1.27 - 1.90	0.050 - 0.075	0.64 ± 0.08	0.025 ± 0.003	2.04
TMS-SCE-1K- <sup>1</sup> / <sub>8</sub> -2.0- <color>	3.18	0.125	1.07	0.042	1.11 - 2.66	0.044 - 0.105	0.58 ± 0.08	0.023 ± 0.003	2.03
TMS-SCE-2X-1K- <sup>1</sup> / <sub>8</sub> - <color>	3.18	0.125	1.58	0.062	1.75 - 2.66	0.069 - 0.105	0.64 ± 0.08	0.025 ± 0.003	2.75
TMS-SCE-1K- <sup>3</sup> / <sub>16</sub> -2.0- <color>	4.75	0.187	1.57	0.062	1.75 - 4.06	0.069 - 0.160	0.58 ± 0.08	0.023 ± 0.003	2.68
TMS-SCE-2X-1K- <sup>3</sup> / <sub>16</sub> - <color>	4.75	0.187	2.36	0.093	2.54 - 4.06	0.100 - 0.160	0.64 ± 0.08	0.025 ± 0.003	3.62
TMS-SCE-1K- <sup>1</sup> / <sub>4</sub> -2.0- <color>	6.35	0.250	2.11	0.083	2.31 - 5.46	0.091 - 0.215	0.58 ± 0.08	0.023 ± 0.003	3.51
TMS-SCE-2X-1K- <sup>1</sup> / <sub>4</sub> - <color>	6.35	0.250	3.18	0.125	3.81 - 5.46	0.150 - 0.215	0.64 ± 0.08	0.025 ± 0.003	5.94
TMS-SCE-1K- <sup>3</sup> / <sub>8</sub> -2.0- <color>	9.53	0.375	3.18	0.125	3.47 - 8.12	0.137 - 0.320	0.61 ± 0.08	0.024 ± 0.003	5.04
TMS-SCE-2X-1K- <sup>3</sup> / <sub>8</sub> - <color>	9.53	0.375	4.75	0.187	5.59 - 8.12	0.220 - 0.320	0.64 ± 0.08	0.025 ± 0.003	8.50
TMS-SCE-1K- <sup>1</sup> / <sub>2</sub> -2.0- <color>	12.70	0.500	4.22	0.166	4.64 - 10.79	0.183 - 0.425	0.61 ± 0.08	0.024 ± 0.003	6.81
TMS-SCE-2X-1K- <sup>1</sup> / <sub>2</sub> - <color>	12.70	0.500	6.35	0.250	6.99 - 10.79	0.275 - 0.425	0.64 ± 0.08	0.025 ± 0.003	11.45
TMS-SCE-1K-- <sup>3</sup> / <sub>4</sub> -2.0- <color>	19.05	0.750	6.35	0.250	6.99 - 16.25	0.275 - 0.640	0.61 ± 0.08	0.024 ± 0.003	12.03
TMS-SCE-2X-1K- <sup>3</sup> / <sub>4</sub> - <color>	19.05	0.750	9.53	0.375	10.16 - 16.25	0.400 - 0.640	0.76 ± 0.08	0.030 ± 0.003	20.63
TMS-SCE-1K-1-2.0- <color>	25.40	1.000	8.46	0.333	9.29 - 21.59	0.366 - 0.850	0.64 ± 0.08	0.025 ± 0.003	15.35
TMS-SCE-1K-1 <sup>1</sup> / <sub>2</sub> -2.0- <color>	38.10	1.500	19.05	0.750	20.95 - 33.02	0.825 - 1.300	0.51 ± 0.08	0.020 ± 0.003	27.51
TMS-SCE-1K-2-2.0- <color>	50.80	2.000	25.40	1.000	27.94 - 44.95	1.100 - 1.750	0.64 ± 0.08	0.025 ± 0.003	47.27
TMS-SCE-1K-2 <sup>1</sup> / <sub>4</sub> -2.0- <color>	57.15	2.250	19.05	0.750	22.32 - 50.80	0.880 - 2.000	0.76 ± 0.08	0.030 ± 0.003	42.06

Total width as supplied 90.18 mm (3.550 inches) including tape and carrier width.

Figure 4.107 – Labels models

Depending on which cable it is, it will be necessary to choose some complements or others, but for practically all the cables it will be necessary to follow the steps mentioned above.



During this phase, one unit of each cable will be designed, and later, at the time of the budget, the necessary units of each of the cables will be specified in order to know the total material required.

The next step is to design the **TBT** cables, which can be divided into two large groups, the external cables, **CABLES EXT**; and the internal cables, **CABLES INT**.

#### 4.4.2.1 CABLES EXT

These will be the cables outside the rack. As they are external, they will be more exposed to constant handling, and for this reason, they will have to have a sleeve, to keep all the wires together, and, in some cases, protections such as backshells, which will prevent the solder joints from wearing out. The cables belonging to this group are the following:

- W01
- W03
- W05
- W06
- W08
- W50

##### 4.4.2.1.1 W01

This cable, which has already been mentioned in several previous sections, is the cable that will connect the rack to the UUTs. This cable will transmit all the power and communication signals supplied by the rack, and will connect the front of the EIM BOX with the DB DUMMY and the W08. The extreme of the cable that is connected to the EIM BOX will be P1, and the one that is connected to the DB DUMMY and W08, will be P2.

Of all the components it connects, the DB DUMMY is the only one that has defined connectors, which, as we have already seen in the section about this board, are HARTING connectors, which will be distributed in the interfaces of the DB DUMMY in the following way:

- J1: 62 pins PIN
- J2: 62 pins SKT
- J3: 78 pins PIN
- J4: 78 pins SKT
- J5: 26 pins PIN

In order to make the cable production easier, the connector that goes to the W08 will also be manufactured by **HARTING**, and will have 44 pins.

As can be seen in the diagram, the signals arriving at interfaces J1 and J2 will be the communication signals between the EIM BOARD and the UUTs, and the signals arriving at interfaces J3, J4 and J5 will be the power transmission signals arriving from the rack sources. As P2 of the W01 will be connected to the DB, it means that in this cable will be the connectors that fit with the above-mentioned interfaces. As P2 will be several connectors, it will be divided into different sections from P2.a. to P2.f., each one corresponding to one of the interfaces of the DB or W08. These shall be divided as follows:

- P2.a. -> J1 of DB
- P2.b. -> J2 of DB
- P2.c. -> W08
- P2.d. -> J3 of DB
- P2.e. -> J4 of DB
- P2.f. -> J5 of DB

Once you know where each part of P2 is going to fit, the connectors are selected, which will be the same as in the DB, but in reverse, meaning that if a connector is male in the DB, it will be female in W01, and vice versa. As J1 on the DB is a 62-pin male connector, P2.a. will be a 62-pin female connector, and filtering on the **RS Component** page indicated by the number of pins and the type, the following connector is obtained:

### Conector D-sub HARTING, paso 2.42mm, Recta D-Sub de alta densidad, Montaje de Cable, Hembra, Terminación Soldador C,

Código RS: 923-0516 | N° ref. fabric.: 09564004704 | Fabricante: HARTING



50 Disponible para entrega en 24/48 horas

Precio unitario (En una caja de 50)

**6,382 €** **7,722 €**  
(exc. IVA) (inc. IVA)

unidades	Por unidad	Por Caja*
50 - 50	6,382 €	319,10 €
100 +	5,425 €	271,25 €

\*precio indicativo

-

+
unidades

Añadir

Figure 4.108 – W01\_P2.a.

Doing the same thing with the next one, as J2 in the DB is a connector with 62 female contacts, we change the gender filter on the page and we obtain the model we are interested in for P2.b.:

**Conector D-sub HARTING, paso 2.42mm, Recta D-Sub de alta densidad, Montaje de Cable, Macho, Terminación Soldador C, 2.0A** 

Código RS: 923-0540 | N° ref. fabric.: 09564005604 | Fabricante: HARTING



50 Disponible para entrega en 24/48 horas

Precio unitario (En una caja de 50)

**5,735 €** (exc. IVA) **6,939 €** (inc. IVA)

unidades	Por unidad	Por Caja*
50 - 50	5,735 €	286,75 €
100 +	4,875 €	243,75 €

\*precio indicativo

50  unidades

Añadir

Figure 4.109 – W01\_P2.b.

For the third connector, P2.c, a female connector will be chosen, since, as a precaution, the cables that supply power are usually female, and those that receive it are usually male, avoiding in this way unintentional contacts that cause short circuits. Therefore, a 44-pin female connector will be sought, and the following is available from **RS Components**:

**Conector D-sub HARTING, paso 2.29mm, Recta D-sub con contactos mixtos, Montaje de Cable, Hembra, Terminación Soldador** 

Código RS: 666-2887 | N° ref. fabric.: 09563004704 | Fabricante: HARTING



Precio Unidad

**5,67 €** (exc. IVA) **6,86 €** (inc. IVA)

unidades	Por unidad
1 - 9	5,67 €
10 - 19	5,09 €
20 +	4,55 €

1  unidades


Añadir

Figure 4.110 – W01\_P2.c.

P2.d. will be the connector that fits the 78-pin male connector of the DB DUMMY, and



therefore, applying the filters for a 78-pin female connector, the following result is obtained:

**Conector D-sub HARTING, paso 2.42mm, Recta D-Sub de alta densidad, Montaje de Cable, Hembra, Terminación Soldador D,** 

Código RS: 923-0522 | N° ref. fabric.: 09565004704 | Fabricante: HARTING



100 Disponible para entrega en 24/48 horas

Precio unitario (En una caja de 50)

**8,559 €**  
(exc. IVA)

**10,356 €**  
(inc.IVA)

unidades	Por unidad	Por Caja*
50 - 50	8,559 €	427,95 €
100 +	7,275 €	363,75 €

\*precio indicativo

-

+
unidades

Añadir

Figure 4.111 – W01\_P2.d.

4

In P2.e., the same model as above will be used, but with male pins. Although power will be transmitted through this cable, an exception is made in this case, and a male connector is used, so that there is no confusion later when connecting them in the DB DUMMY. By setting the required filters on the **RS Component** page, the following price is obtained:

**Conector D-sub HARTING, paso 2.42mm, Recta D-Sub de alta densidad, Montaje de Cable, Macho, Terminación Soldador D, 2.0A** 

Código RS: 923-0547 | N° ref. fabric.: 09565005604 | Fabricante: HARTING



Precio unitario (En una caja de 50)

**7,816 €**  
(exc. IVA)

**9,457 €**  
(inc.IVA)

unidades	Por unidad	Por Caja*
50 - 50	7,816 €	390,80 €
100 +	6,643 €	332,15 €

\*precio indicativo

-

+
unidades

Añadir

Figure 4.112 – W01\_P2.e.

To finish with P2, the P2.f. connector, will have to fit with a 26-pin male connector, so by setting the filters on the page, it will give the following connector:

### Conector D-sub HARTING, paso 2.29mm, Recta D-Sub de alta densidad, Montaje de Cable, Hembra, Terminación Soldador A,

Código RS: 923-0525 | N° ref. fabric.: 09562004704 | Fabricante: HARTING



200 Disponible para entrega en 24/48 horas

Precio unitario (En una caja de 100)

**3,051 €** (exc. IVA) **3,692 €** (inc.IVA)

unidades	Por unidad	Por Caja*
100 - 100	3,051 €	305,10 €
200 +	2,593 €	259,30 €

\*precio indicativo

unidades

Añadir

Figure 4.113 – W01\_P2.f.

Now that P2 is finished, the next step is to choose the connectors for P1. To make the cable simpler, it will be made pin by pin, so that the cable W01 will be made up of 6 individual cables, which will be joined in the centre by a flexible label, or some kind of rope. For the P1 connectors, the opposite of P2 will be chosen, in other words, the same as those of the DB DUMMY, but with cable mounting; in this way, the W01 will be like an extension of the DB DUMMY that will allow the mobility of the rack or the UUTs, without affecting each other.

As in the P2 design there are several connectors that have the same number of pins but are opposite, there will be no need to look for them again, as they have already been found before. In this way, there will be a correspondence between the following connectors:

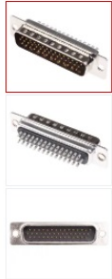
- P2.a. -> P1.b.
- P2.b. -> P1.a.
- P2.d. -> P1.e.
- P2.e. -> P1.d.

For P1.c., however, if it will be necessary to search for a model opposite to the one found for P2.c., and by adding the 44-pin male filters, it is possible to find the following connector:

### Conector D-sub HARTING, paso 2.29mm, Recta D-Sub de alta densidad, Montaje de Cable, Macho, Terminación Soldador B, 2.0A



Código RS: 923-0531 | N° ref. fabric.: 09563005604 | Fabricante: HARTING



Precio unitario (En una caja de 100)

**3,978 €**  
(exc. IVA)

**4,813 €**  
(inc.IVA)

unidades	Por unidad	Por Caja*
100 - 100	3,978 €	397,80 €
200 +	3,381 €	338,10 €

\*precio indicativo

- 100 + unidades

**Añadir**

Figure 4.114 – W01\_P1.c.

# 4

With P1.f. it is the same as with P1.c., it will be necessary to look for the opposite of the one found for P2.f., and, for this reason, looking on the **RS Component** website for a connector with 26 male pins, the following model appears:

### Conector D-sub HARTING, paso 2.29mm, Recta D-Sub de alta densidad, Montaje de Cable, Macho, Terminación Soldador A, 2.0A



Código RS: 923-0538 | N° ref. fabric.: 09562005604 | Fabricante: HARTING



Precio unitario (En una caja de 100)

**2,544 €**  
(exc. IVA)

**3,078 €**  
(inc.IVA)

unidades	Por unidad	Por Caja*
100 - 100	2,544 €	254,40 €
200 - 200	2,163 €	216,30 €
300 - 400	1,908 €	190,80 €
500 - 900	1,654 €	165,40 €
1000 +	1,527 €	152,70 €

\*precio indicativo

- 100 + unidades

**Añadir**

Figure 4.115 – W01\_P1.f.

Therefore, the following connectors are required for the W01 cable:

- 2x 78-pin male connector
- 2x 78-pin female connector
- 2x 62-pin male connector
- 2x 62-pin female connector
- 1x 44-pin male connector
- 1x 44-pin female connector
- 1x 26-pin male connector
- 1x 26-pin female connector

Once you have all the connectors, the cable plan is drawn, but for this purpose it is necessary to know the length of the cable first. When the UUTs are under test, they may be located in thermal or vacuum chambers, where the rack cannot be, so the cable length must be long enough to be able to separate the rack from the UUTs without tension between the cables.

In order to be able to work without problems, a length of 3m was chosen for the W01 cable. A length that will allow full manoeuvrability without affecting the performance of the tests. The plan will then be as follows:

4

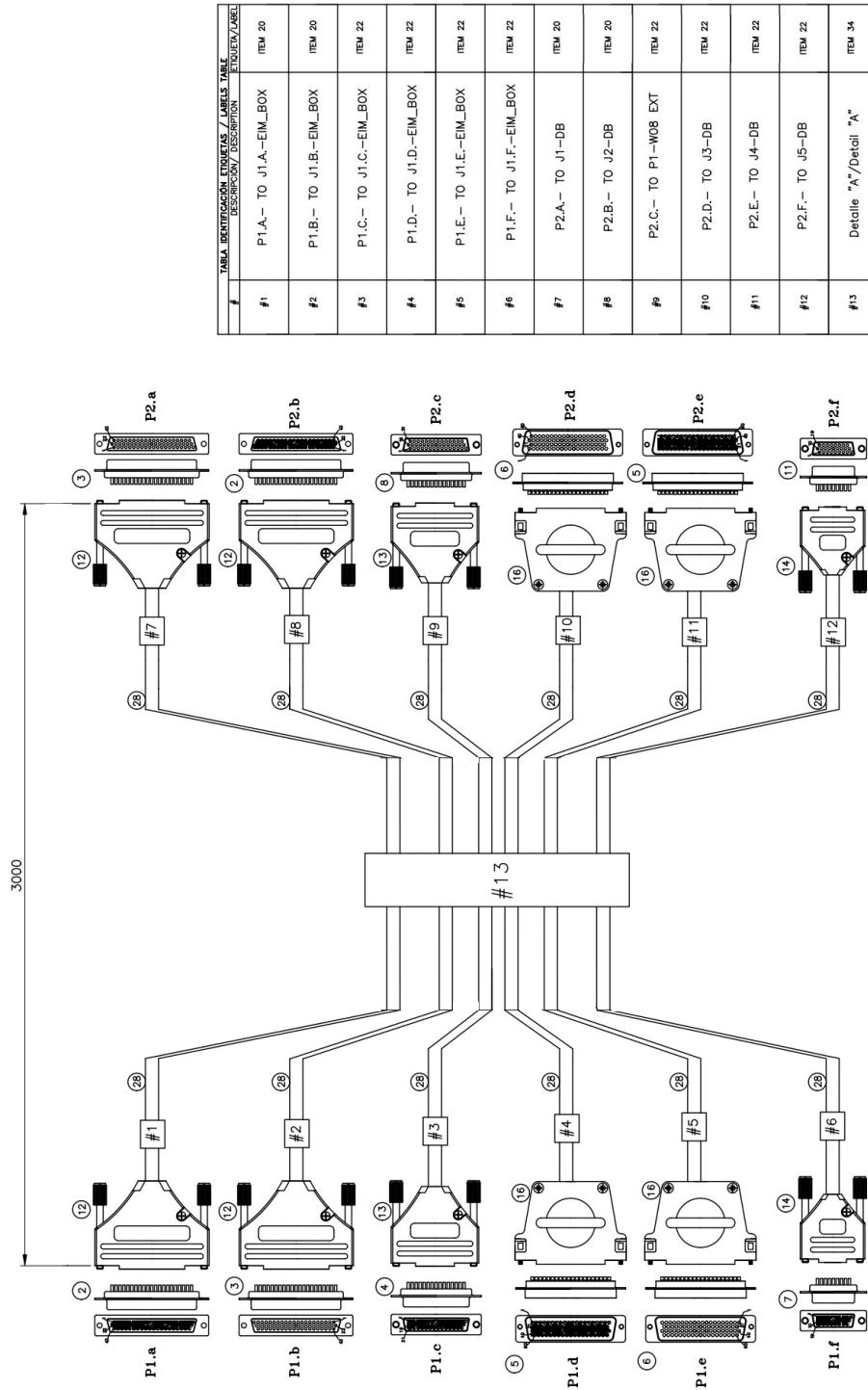


Figure 4.116 – W01 plan and labels



Now it is calculated how much wire will be needed for the cable W01. As not all signals will be the same, different wire thicknesses will be used.

For the sections of the cable that will carry communications signals (P1.a. to P2.a. and P1.b. to P2.b.), an **AWG26** conductor will be used, and for the sections that carry power, **AWG22** will be used. As this cable will be pin to pin, the number of conductors to be used will be the same as the number of pins in the cable, so adding up all the pins of the connectors on one side, we get a total of:

$$\text{TOTAL WIRES} = 62 + 62 + 44 + 78 + 78 + 78 + 26 = 350$$

The number of conductors that will be used in total will be 347, of which 124 will be for the transport of communication signals, and therefore **AWG26**; and the other 223 will be for the transport of power, and therefore **AWG22**. Multiplying the number of conductors of each type by the length of the cable, the following quantity of conductors is obtained:

$$\text{AWG26 CONDUCTOR: } 124 \text{ wires} \times 3\text{m} = \mathbf{372\text{m}} \text{ of AWG26.}$$

$$\text{AWG22 CONDUCTOR: } 226 \text{ wires} \times 3\text{m} = \mathbf{678\text{m}} \text{ of AWG22}$$

Once all the connectors and quantity of cable required are in place, the necessary complements for the cable are calculated. As it is an external cable, all the sections will be protected by a polyester sleeve, but in this case, as the two communication signal sections are very long cables and will be exposed to environments with possible noise, they will also be protected with a copper sleeve, which will act as a Faraday cage, and will guarantee the integrity of the signal along the entire route between the EIM BOX and the DB DUMMY. The other sections, as they are not sensitive signals for the correct communication of the system, will not have to carry this additional protection.

Applying the formula seen in the section of the TBT cables for the calculation of sleeves and labels, the following calculations are made, knowing that the thickness of the wire of **AWG 26** is 1.00 and that of **AWG22** is 1.27:

$$\text{SECTION RADIUS W01.A.} = \text{sqrt}(62 * 0.5 * 0.5) = \mathbf{3.93}$$

$$\text{SECTION RADIUS W01.B.} = \text{sqrt}(62 * 0.5 * 0.5) = \mathbf{3.93}$$

$$\text{SECTION RADIUS W01.C.} = \text{sqrt}(44 * 1.27 * 1.27) = \mathbf{8.42}$$

$$\text{SECTION RADIUS W01.D.} = \text{sqrt}(78 * 1.27 * 1.27) = \mathbf{11.21}$$

$$\text{SECTION RADIUS W01.E.} = \text{sqrt}(78 * 1.27 * 1.27) = \mathbf{11.21}$$

$$\text{SECTION RADIUS W01.F.} = \text{sqrt}(26 * 1.27 * 1.27) = \mathbf{6.47}$$

Multiplying the obtained radiuses by two to obtain the diameters, the following measurements are obtained:

RAMAL	RADIUS	DIAMETER
W01.A.	3.93	7.86
W01.B.	3.93	7.86
W01.C	8.42	16.84
W01.D	11.21	22.42
W01.E.	11.21	22.42
W01.F.	6.47	12.95

With this diameter, it is possible to search now in the tables where the thicknesses of the sleeves are given, for the one that best suits each of the sections of the W01. These models will be the following:

RAMAL	DIAMETER	BRAIDED SLEEVING	LENGTH
W01.A.	7.86	GRP-110-1/2	3
W01.B.	7.86	GRP-110-1/2	3
W01.C	16.84	GRP-110-3/4	3
W01.D	22.42	GRP-110-3/4	3
W01.E.	22.42	GRP-110-3/4	3
W01.F.	12.95	GRP-110-1/2	3

4

To find the cooper sleeve that will protect W01.A., and W01.B., it is necessary to look at the following table of sleeves:

Alpha Part No.	Nom. I.D. When Rounded		Braid Construction			Approx. AWG Equiv.	Nom. Circular Mil Area, CM	Approx. Current Carrying Cap. (Amps)†	Standard Package Spools Ft.
	Inches	mm	AWG of Indiv. Ends	Carriers	Total No. of Indiv. Ends				
<b>TINNED COPPER TUBULAR BRAID</b>									
2160	1/32	0,79	36	24	24	22	600	7.0	100, 250
2162	1/16	1,59	36	24	48	19	1200	11.0	100, 250
2163	5/64	1,98	36	24	72	18	1800	16.0	100, 250
2164	7/64	2,78	36	24	96	16	2400	19.0	100, 250
2166	1/8	3,18	36	24	120	15	3000	25.0	100, 250
2167	5/32	3,97	36	24	240	12	6000	40.0	100, 250
2168	11/64	4,37	36	24	168	14	4200	32.0	100, 250
2170	13/64	5,16	34	24	192	11	7630	46.0	100
2171	1/4	6,35	36	24	384	10	9600	53.0	100
2171/1	9/32	7,14	30	24	120	9	12060	60.0	100
2172	3/8	9,53	36	48	384	10	9600	53.0	100
2173	7/16	11,11	30	24	240	6	24120	90.0	100
2174	1/2	12,70	36	48	528	9	13200	62.0	100
2175	9/16	14,29	30	48	480	3	48240	145.0	100
2175/1	21/32	16,67	30	48	768	1	77180	190.0	100
2176	25/32	19,84	36	48	864	7	21600	88.0	100

Figure 4.117 – Cooper sleeve models

In this table, and looking at the diameter measurements for the selected sections, the model **2172** is chosen, which has a price of 1.42€ per meter. This price per meter suppose a total price of  $6 * 1.42€ = 8.52€$ .

MALLA COBRE TUBULAR Ø12.5mm Sn	Mat	1,69
MALLA COBRE TUBULAR Ø10mm Sn	Mat	1,42
MALLA COBRE TUBULAR Ø7.5mm Sn	Mat	1,34

Figure 4.118 – Cooper sleeve price

For the labels to be used, as can be seen in the cable plan identification table, there will be three types, the **ITEM 20**, the **ITEM 22**, and the **ITEM 34**. These will be chosen according to the cable diameter, as the same as the sleeves, but looking at the table of the label models:

LABEL	MODEL	QUANTITY
ITEM 20	TMS-SCE-2X-1K-1/2	4
ITEM 22	TMS-SCE-1K-1-2.0	8

The **ITEM 34** will be a label that will be placed around the whole cable harness, and will be responsible for holding them together. It is made up of a white part where the label code is printed, and a long transparent adhesive part.

This cable will also have backshells, which are pieces that are responsible for holding the connector, and protect the cable from possible damage. This piece is placed in this cable because as it is responsible for connecting the whole rack with the UUTs, it will be continuously plugged and unplugged, and without the backshells, it would most likely cause stress on the soldering, which would lead to a malfunction of the cable.

Each model of backshell indicates the pins that the connector must have to fit in it, but as the connectors to be used are of high density, to choose the model of backshell, it will be necessary to look at the measurements between the screws of the backshell and between the external holes of the connector, and the height of each one of these.

Starting with the 62-pin connectors, according to their datasheet, they have an outer hole spacing of 63.50mm, and a height of 12.55mm.



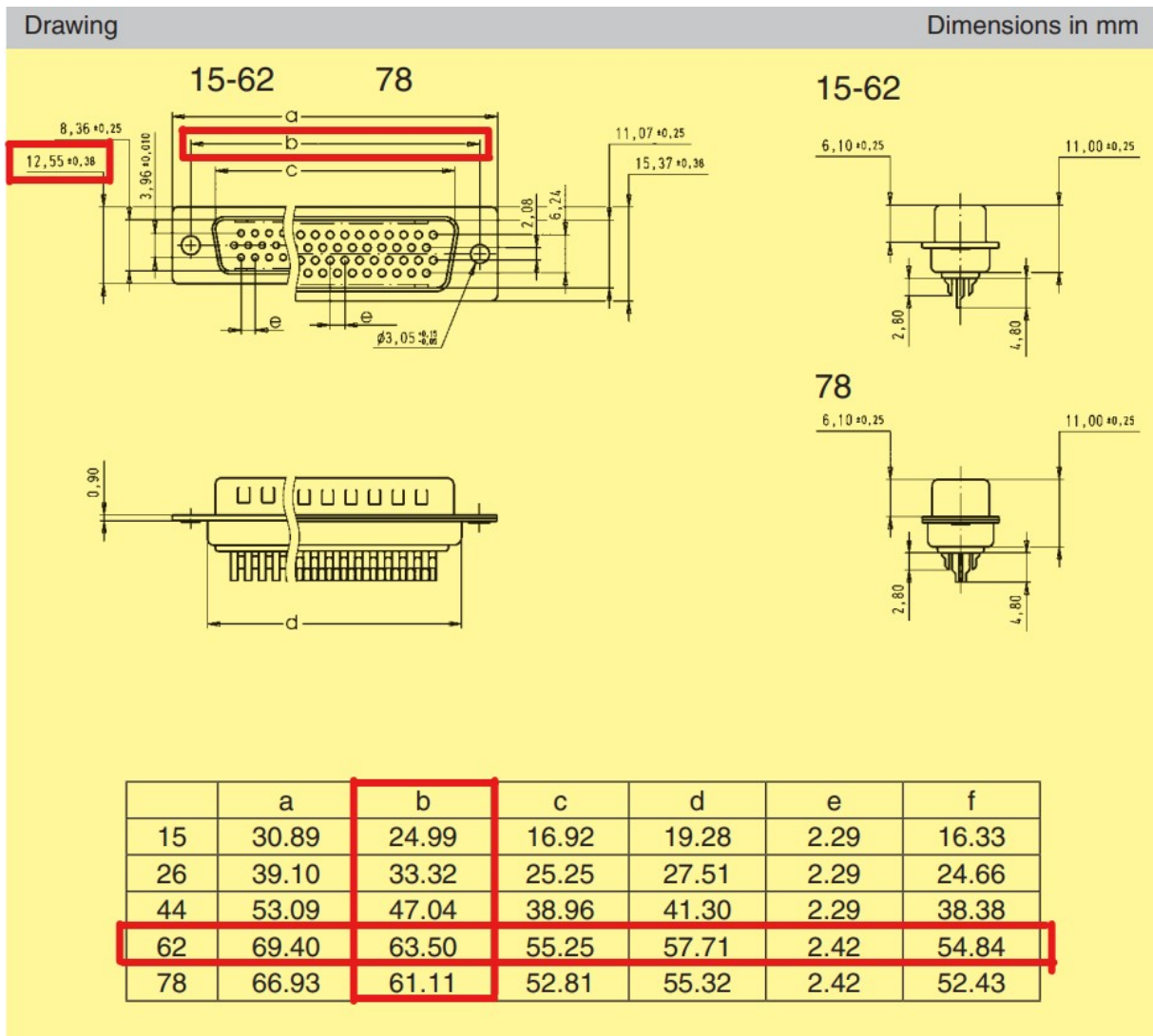


Figure 4.119 – 62 pin’s connector dimensions

On the **RS Component** website, under D Sub housings, filtering by number of pins, and selecting 37W, it is possible to find a backshell from the company **MH Connectors** whose measurements match with those of the connector.

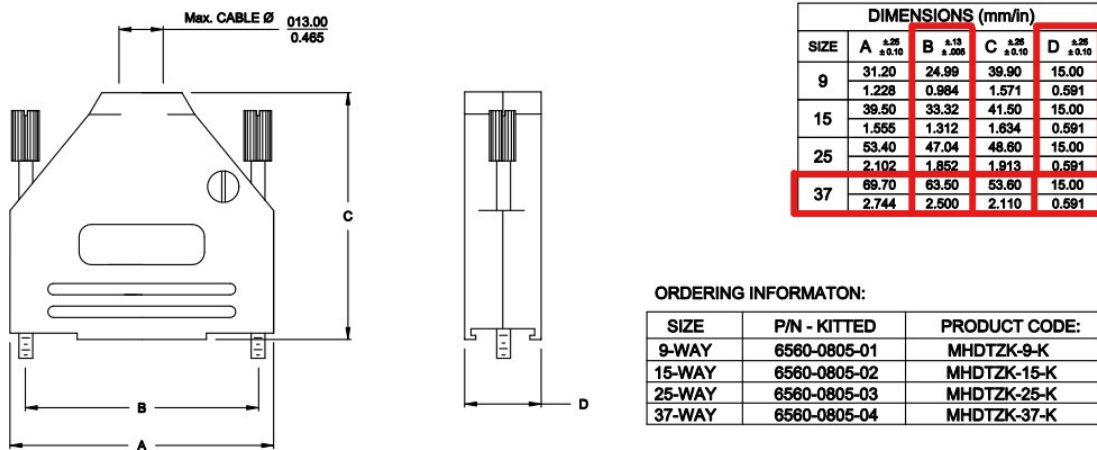


Figure 4.120 – 37W backshell dimensions

The height of the connector and the backshell are not exactly the same, this is because the height of the backshell, as you can see in the drawing, has to be reduced by the thickness of the material, which would mean a value much closer to the 12.55mm that is being looked for. This backshell, being valid for 62-pin connectors, will have to be purchased 4 times, and its value on the RS Component website will be as follows:

**Carcasa de conector D-sub SérieMHDTZK-RA, Recta, 37 contactos Zinc, Plateado,**

Código RS: 454-946 | N° ref. fabric.: MHDTZK37-RA-PC-K | Fabricante: MH Connectors

unidades	Por unidad
1 - 24	8,15 €
25 - 99	7,13 €
100 - 249	6,11 €
250 - 499	5,50 €
500 +	4,89 €

781 Disponible para entrega en 24/48 horas

Precio Unidad  
**8,15 €** (exc. IVA)      **9,86 €** (inc.IVA)

1 unidades      Añadir

Figure 4.121 – 37W backshell price

The same action is now repeated for the two 44-pin connectors, and looking at the datasheet, the following measurements are obtained:



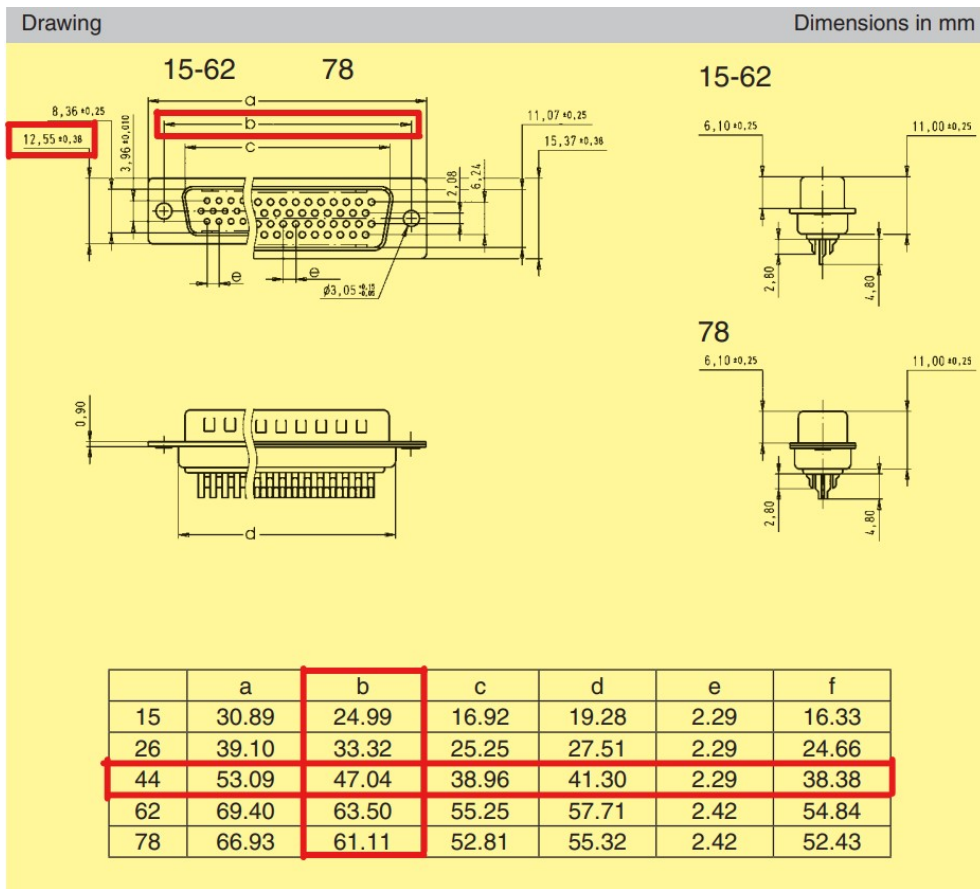


Figure 4.122 – 44 pin's connector dimensions

Looking at the datasheet of the previously selected backshell, it is possible to see that the 25W model has the measurements that are being searched for this connector:

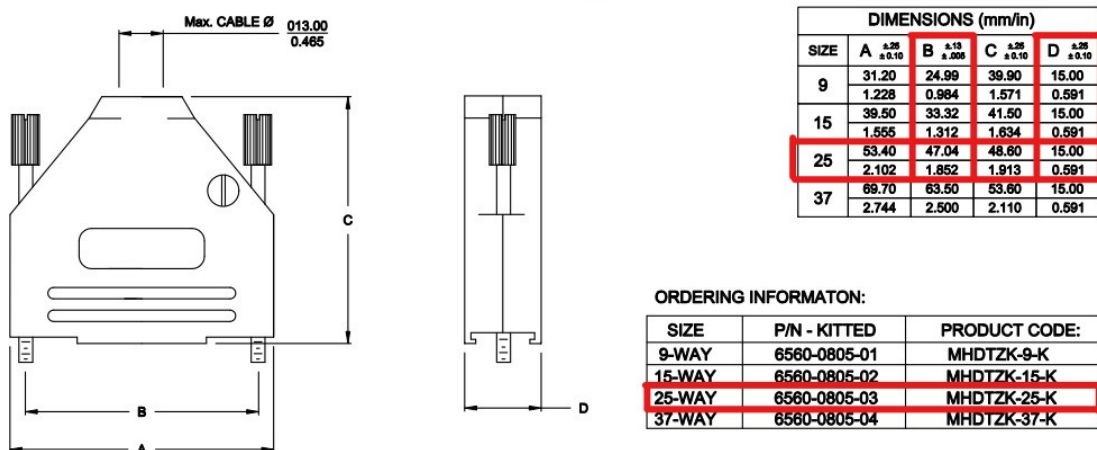



Figure 4.123 – 25W backshell dimensions

Looking for that model on the **RS Component** website, the following price is obtained:

### Carcasa de conector D-sub SérieMHDTZK-RA, Recta, 25 contactos Zinc, Plateado,

Código RS: 460-979 | N° ref. fabric.: MHDTZK25-RA-PC-K | Fabricante: MH Connectors



**19314 Disponible para entrega en 24/48 horas**

Precio Unidad  
**6,23 €**  
 (exc. IVA) **7,54 €**  
(inc.IVA)

unidades	Por unidad
1 - 24	6,23 €
25 - 99	5,43 €
100 - 249	5,35 €
250 - 499	4,64 €
500 +	4,43 €

unidades

Figure 4.124 – 25W backshell price

As this backshell will be used for 44-pin connectors, it will be purchased twice, for P1.c. and P2.c. For 26-pin connectors, the same is done, by first looking at their datasheet:

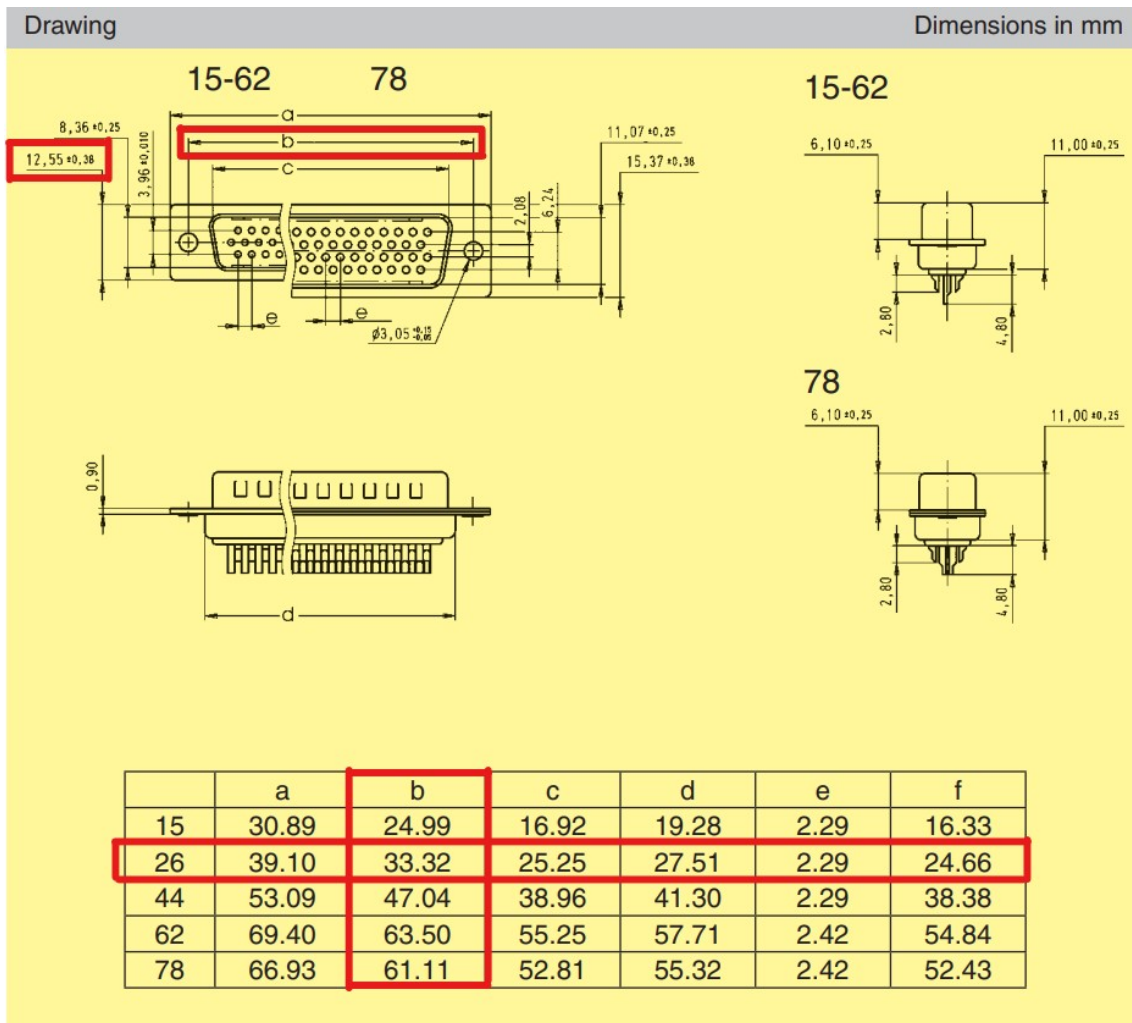


Figure 4.125 – 26 pin’s connector dimensions

Looking for a backshell for this connector, it is possible to see that it matches also one of the already chosen models, namely the 15W model:



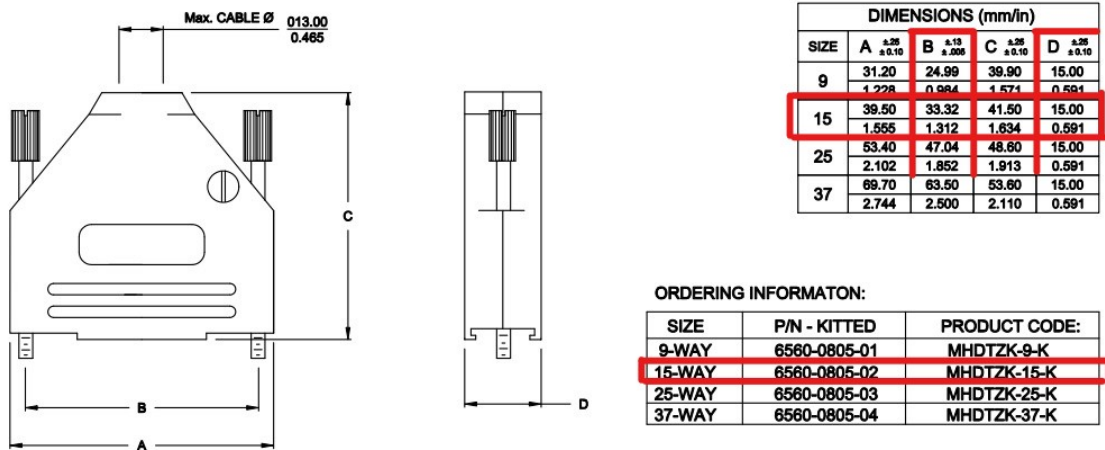


Figure 4.126 – 15W backshell dimensions

Looking for it on the RS Component website, it is available for the following price:

**Carcasa de conector D-sub SérieMHDTZK-RA, Recta, 15 contactos Zinc, Plateado, MH CONNECTORS**

A

Código RS: 454-930 | N° ref. fabric.: MHDTZK15-RA-PC-K | Fabricante: MH Connectors

unidades	Por unidad
1 - 24	3,86 €
25 - 74	3,59 €
75 - 199	3,23 €
200 - 399	2,92 €
400 +	2,74 €

Figure 4.127 – 15W backshell price

This connector will fit the 26-pin connectors, and therefore you will also have to buy two, one for P1.f., and one for P2.f.

For 78-pin connectors, the following dimensions are available:

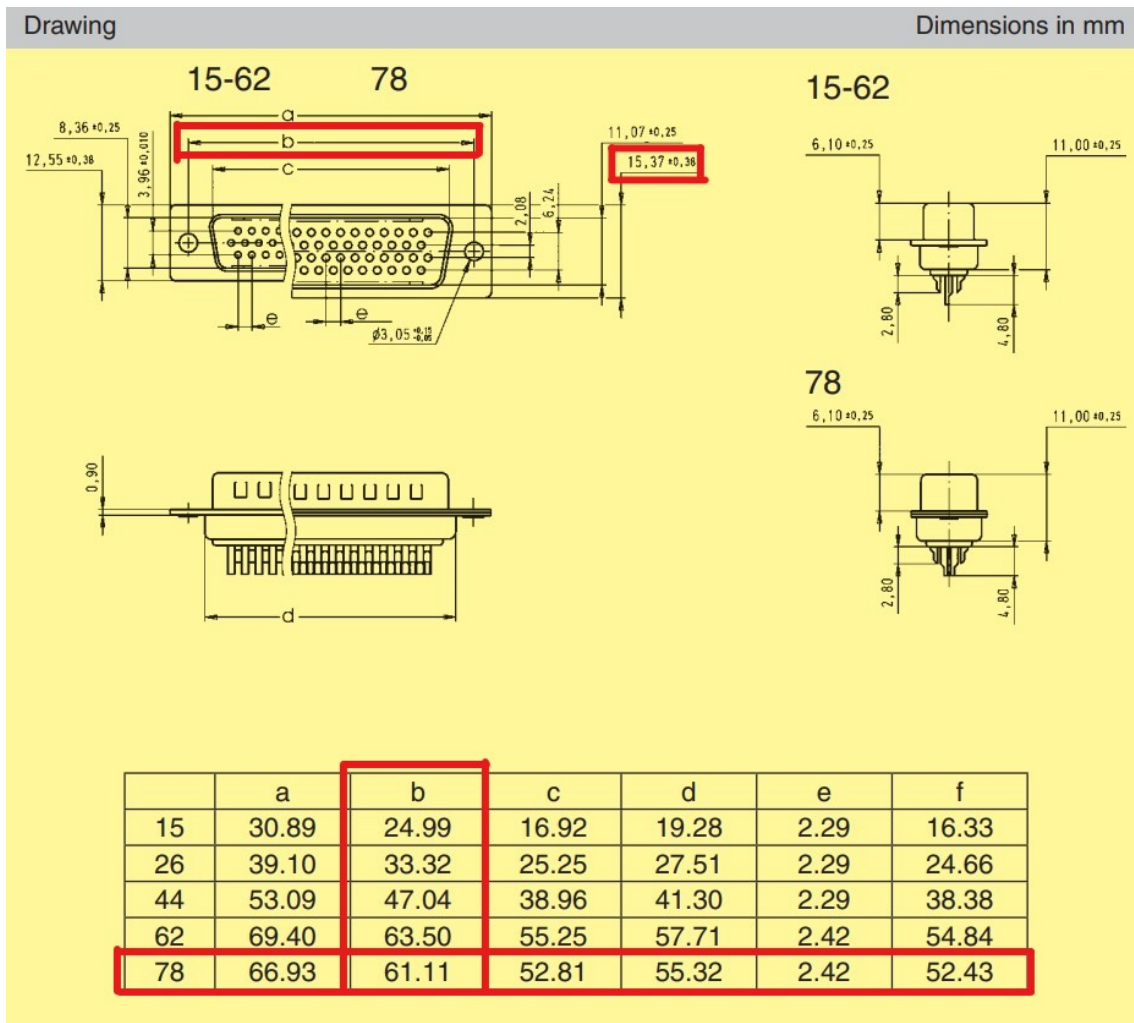


Figure 4.128 – 78 pin's connector dimensions

For these connectors there is none of the previous backshell models that fit with them, but filtering on the **RS Component** page by pin numbers 50W, there is a model from the same company that meets the requirements of the measurements:

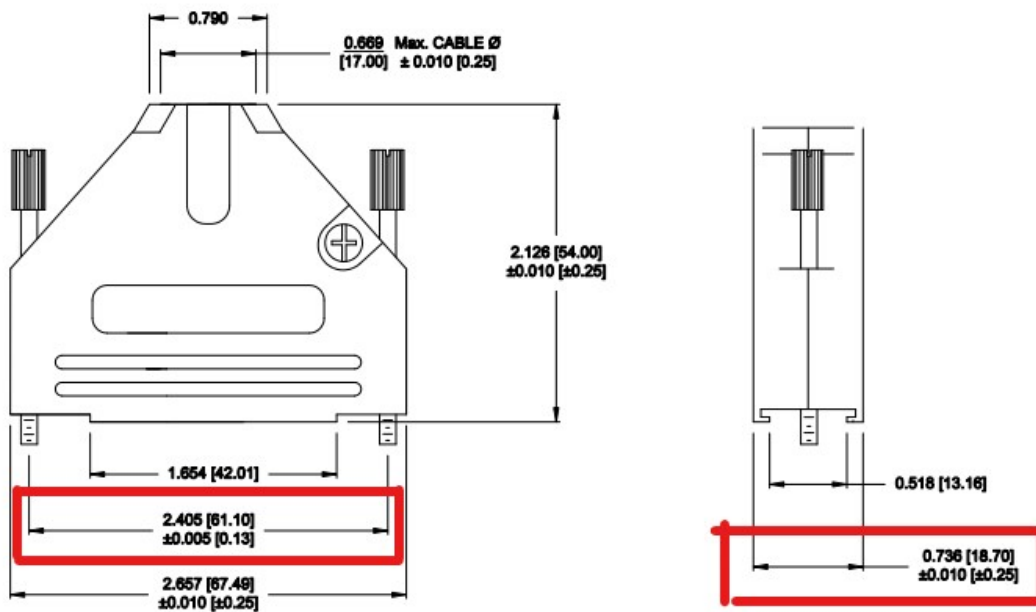


Figure 4.129 – 50W backshell dimensions

For this model it would be necessary to buy 4 units, which would be responsible for protecting the four 78-pin connectors that will be used in this cable. The price in **RS Components** web is as follows:

**Carcasa de conector D-sub SérieMHDTZK, Recta, 50 contactos Zinc, Plateado, D** 

Código RS: 720-3023 | Nº ref. fabric.: MHDTZK50-RS-K | Fabricante: MH Connectors



272 Disponible para entrega en 24/48 horas

Precio Unidad  
**7,10 €**  
(exc. IVA)

**8,59 €**  
(inc. IVA)

unidades	Por unidad
1 - 9	7,10 €
10 - 24	6,40 €
25 - 49	6,06 €
50 - 99	5,37 €
100 +	4,97 €

1  unidades

Añadir

Figure 4.130 – 50W backshell price

This completes the design of the W01, and the next cable is designed.



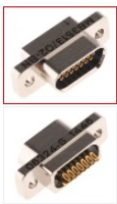
#### 4.4.2.1.2 W03

This cable will be used to make measurements inside the DL HEAD, to check that the signals are arriving correctly, and that there are no problems during the transmission of these.

The extreme of the cable connected to the DL HEAD will be connected to the J5 interface of the DL HEAD, and, looking at the requirements chapter, in the DL HEAD section, it is possible to see that this interface corresponds to a 15-pin connector of the MDM type with male pins. MDM connectors are military and aerospace connectors that are able to work under extreme temperature and pressure conditions. They are manufactured by various companies in the electronics industry, and within [Tecnobit-Grupo Oesia](#) usually rely on the company **GLENAIR** to manufacture them. These connectors are available on the **RS Component** website in the Micro-D connector category. Applying the filters **GLENAIR** manufacturer, number of contacts 15, and female type, the following model is obtained:

#### Conector D-sub Glenair, Serie M83513, Recta Micro-D, Montaje de Cable, Hembra, Terminación Soldador

Código RS: 719-5900 | N° ref. fabric.: M83513/02-BN | Fabricante: [Glenair](#)



16 Disponible para entrega en 24/48 horas

Precio Unidad

**67,48 €**  
(exc. IVA)

**81,65 €**  
(inc. IVA)

unidades	Por unidad
1 - 24	67,48 €
25 - 74	65,60 €
75 - 199	63,83 €
200 - 399	62,15 €
400 +	60,56 €

- 1 + unidades

Añadir

Figure 4.131 – W03 connector

This will be one of the extremes of the cable W03, the other extreme of the cable, as it will be used to make measurements of the signals that reach the DL HEAD, will have to be able to introduce sensors or measuring tools. For this purpose, a breadboard and male and female connectors will be used, so that the sensors can be inserted into the contacts and a correct measurement can be ensured.

The first step is to select the breadboard. As there are no requirements for its operation, a normal breadboard will be found on the **RS Component** website.

**Placa de matriz RE200-HP, Single Sided, FR2, orificios: 38 x 61, diámetro 1mm, paso 2.54 x 2.54mm, 160 x 100 x 1.5mm**



Código RS: 206-8648 | N° ref. fabric.: RE200-HP | Fabricante: Roth Elektronik

The image shows a brown breadboard with a grid of holes. Dimensions are provided: 160.15 mm width, 100.20 mm height, and a 2.54 mm pitch. The Roth Elektronik logo is visible on the board. To the right is a price table and a quantity selector.

unidades	Por unidad
1 - 9	3,95 €
10 - 19	3,93 €
20 - 49	3,90 €
50 +	3,88 €

Price: 3,95 € (exc. IVA) / 4,78 € (inc. IVA)

Quantity: 1 unidades

Buttons: - 1 + unidades, Añadir

Figure 4.132 – W03 breadboard

This model has individual sockets, meaning that they are not connected to each other, and their spacing is 2.54 x 2.54 mm. To find the connectors, go to the Cable housings and PCB connectors section of the **RS Component** website and look for both male and female connectors.

In the case of female connectors, look for 3-contact connectors, to leave the middle contact empty, and to be able to measure on the two contacts at the extremes without the risk of an accidental short.

In the case of male connectors, however, two consecutive pins should be selected, as a jumper may be used in the future to allow an intentional short-circuit, changing some characteristic of the circuit.

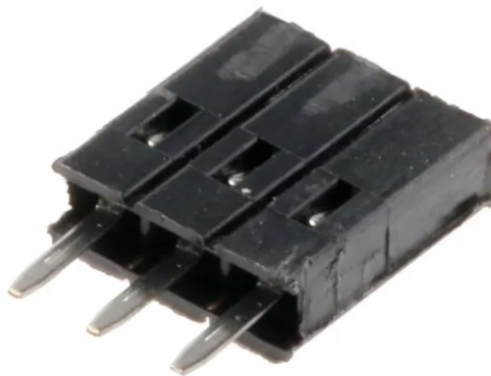
Searching the **RS Component** website, as usual, and, filtering by a 2.54mm pitch and the number of contacts required, it is possible to find the following models of male and female connectors:



## Conector hembra para PCB RS PRO Recta 3 pines 1 fila pasaje 2.54mm Montaje Orificio Pasante Terminación Soldada



Código RS: 251-8187 | Fabricante: RS PRO



2800 Disponible para entrega en 24/48 horas

Precio unitario (Suministrado en múltiplos de 10)

**0,504 €**  
(exc. IVA)

**0,61 €**  
(inc. IVA)

unidades	Por unidad	Por Pack*
10 - 190	0,504 €	5,04 €
200 - 740	0,419 €	4,19 €
750 - 2990	0,353 €	3,53 €

- 10 + unidades

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Figure 4.133 – W03 female connector

4

## Cabezal de pines, RS PRO, Recta 2 pines 1 fila pasaje 2.54mm 7.0mm, Terminación Soldada 3.0mm No Recubierto,



Código RS: 251-8086 | Fabricante: RS PRO



1625 Entrega en 24 horas

119625 Disponible para entrega en 24/48 horas

Precio unitario (Suministrado en múltiplos de 25)

**0,113 €**  
(exc. IVA)

**0,137 €**  
(inc. IVA)

unidades	Por unidad	Por Pack*
25 - 600	0,113 €	2,825 €
625 - 1225	0,096 €	2,40 €
1250 - 2475	0,085 €	2,125 €

- 25 + unidades

Añadir

Figure 4.134 – W03 male connector

Once the connectors have been chosen, the next step is to draw the cable, which will have a plan like the following one:

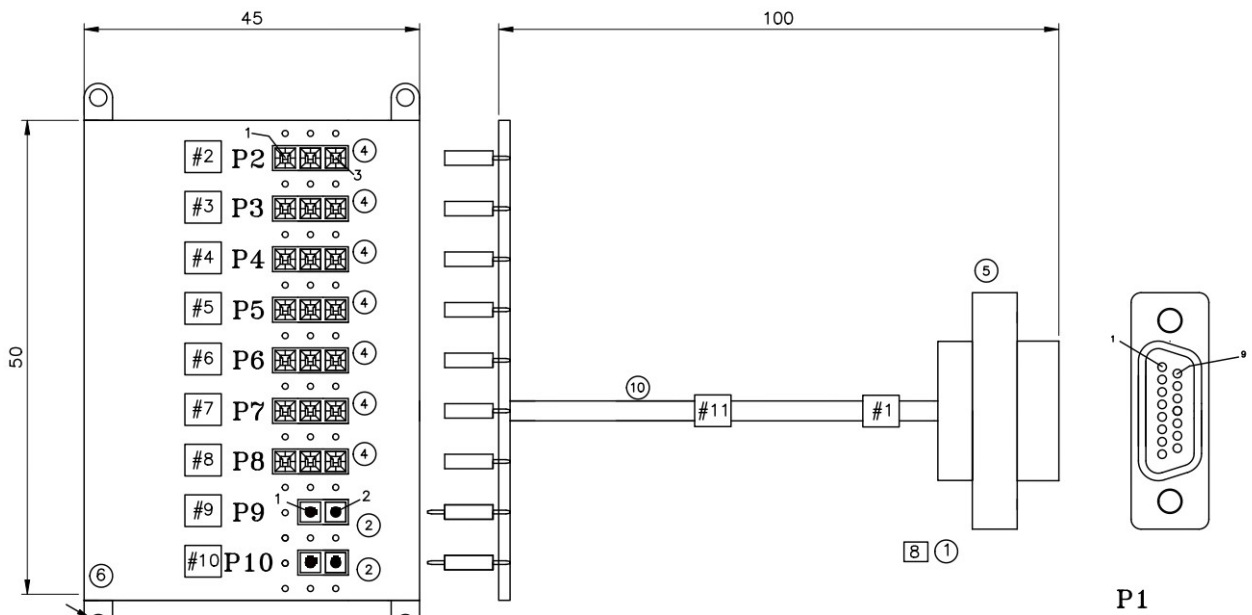


Figure 4.135 – W03 plan

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	P1 – J5 DL HEAD	ITEM 9
#2	P2 – SIGNALS	ITEM 9
#3	P3– FLOAT GND SYS	ITEM 9
#4	P4– VCC2/VSS	ITEM 9
#5	P5 – VDD MCCM	ITEM 9
#6	P6 – VDD SC	ITEM 9
#7	P7 – VDD LNA	ITEM 9
#8	P8 – VG SSPA	ITEM 9
#9	P9 – TEST STRAP N	ITEM 9
#10	P10 – TEST STRAP R	ITEM 9
#11	DETALLE "A"/DETAIL "A"	ITEM 9

Figure 4.136 – W03 label

The length of the cable is so short because, since it is a measurement cable, it will not always be connected, and when it is, it will be to measure close to the board in case of possible errors. The wire for this cable will be **AWG26**, because the P1 connector, as it is a high-density connector, will not accept wires thicker than **AWG26**, and, although at first sight it could seem a problem because power signal measurements are made too, the distance is so short that it will not affect the signal, and therefore not the measurements either.

So, in order to calculate the amount of wire to be used, it is necessary to know at which extreme more connectors are used, left or right. As mentioned above, 2 of the 3 female contacts will be used, and as there are 7 connectors, this gives a total of 14 contacts in use. For the male connectors, it has been seen that both pins are used, and therefore, all 4 pins are used, which means that 18 contacts will be used on the breadboard. On the right side, P1, the 15 contacts of the connector will be used.

During the manufacture of the cable, soldering will have to be done between different wires so that these 15 contacts become 18. These instructions are indicated in the PINOUT of the cable, which will not be shared for confidentiality reasons. But this means that eighteen 100mm cables will have to come out of the breadboard to the P1 connector. Multiplying now, we get the amount of AWG26 cable to be used:

$$\text{AWG26 WIRE} = 18 * 100\text{mm} = \mathbf{1800\text{mm}}$$
 of wire.

As this cable is so short, and will not be used so frequently, there will be no need to use a sleeve to protect it, and at most, if it is needed, it will be tied with rope to keep it more rigid.

Due to its size, and the fact that most of the labels are located on the breadboard, adhesive labels belonging to the company will be used for this cable, the cost of which is always estimated to be zero as it is not a major expense.

#### 4.4.2.1.3 W05 y W06

W05 and W06 are the cables that are responsible for connecting the RFCBs to the two MCCMs that are connected to it. Both cables will be explained together, as they are exactly the same, but with the difference of the interfaces they connect. In the case of W05, it is responsible for connecting the J2 interface of the RFCB to the J6 interfaces of the MCCM1 and MCCM2, while W06 is responsible for connecting the J3 interface of the RFCB to the J7 interfaces of the MCCM1 and MCCM2.

Interfaces J2 and J3 of the RFCB are the same, and interfaces J6 and J7 of the MCCMs are the same. In addition, interfaces J2 and J3 are symmetrically located with respect to the centre of the RFCB, and interfaces J6 and J7 of the MCCMs are also symmetrically located with respect to the centre of the boards. Therefore, both cables will be the same and have the same dimensions. The connector that fits the interfaces that are connected to the RFCB, J2 and J3, will be called P1. The connectors of the RFCB interfaces J2 and J3



are 15-pin male MDM, so P1 will be a 15-pin female MDM connector, the same as P1 on W03.

The other two connectors will be the same, as they fit the same interface, but on different boards. On the MCCM, both J6 and J7 are **NICOMATIC** connectors, whose serial number is **221Y06F21**. This connector is made to be placed on a PCB, so in addition to changing the gender value in the serial number, you will also have to change the value for the termination. Filling in the values on the **NICOMATIC** website, you get the serial number **222S06M16**, which is not available on the **NICOMATIC** online shop, but is available on the website of **FUTURE ELECTRONICS**, which is one of the official distributors of the French company.

The screenshot shows a product page for a Nicomatic connector. At the top, there is a breadcrumb trail: "/ Conectores / Zócalos de paquete dual en línea / 222S06M16". Below this, the product name "Nicomatic | 222S06M16" is displayed. On the left, there is a 3D model of the connector and the Nicomatic logo. To the right of the model, the following text is visible: "Manufacturer Part # 222S06M16", "6 Position 2mm Pitch Female Crimp Contact CMM Connector with M16 Hardware", and a link for "Hoja de datos". On the right side of the page, there is a shopping cart interface. It includes a "Cantidad" dropdown menu set to "1", a "Total" of "€28,95 EUR", and a blue button labeled "AÑADIR".

Figure 4.137 – W05 and W06 connector

Once the connectors are in place, the plan can be drawn. Knowing the measurements of the MCCMs, and knowing that for each RFCB Dual there are two MCCMs, it is possible to make an approximate estimation of the distance between each of the connectors that form the cables W05 and W06. Between the RFCB connector and the MCCM1 connector, there will not be a large distance, so 200mm between them is chosen so that the cable does not have to be tense and can be easily fitted. The MCCM2 connector will be at a distance from the MCCM1 connector that is slightly longer than the length of an MCCM board, as both will be next to each other and separated only by a small space. For this purpose a distance between both connectors of 300mm is chosen, as the length of an MCCM board is 120mm, and the cable cannot be tense to guarantee a correct connection.

4

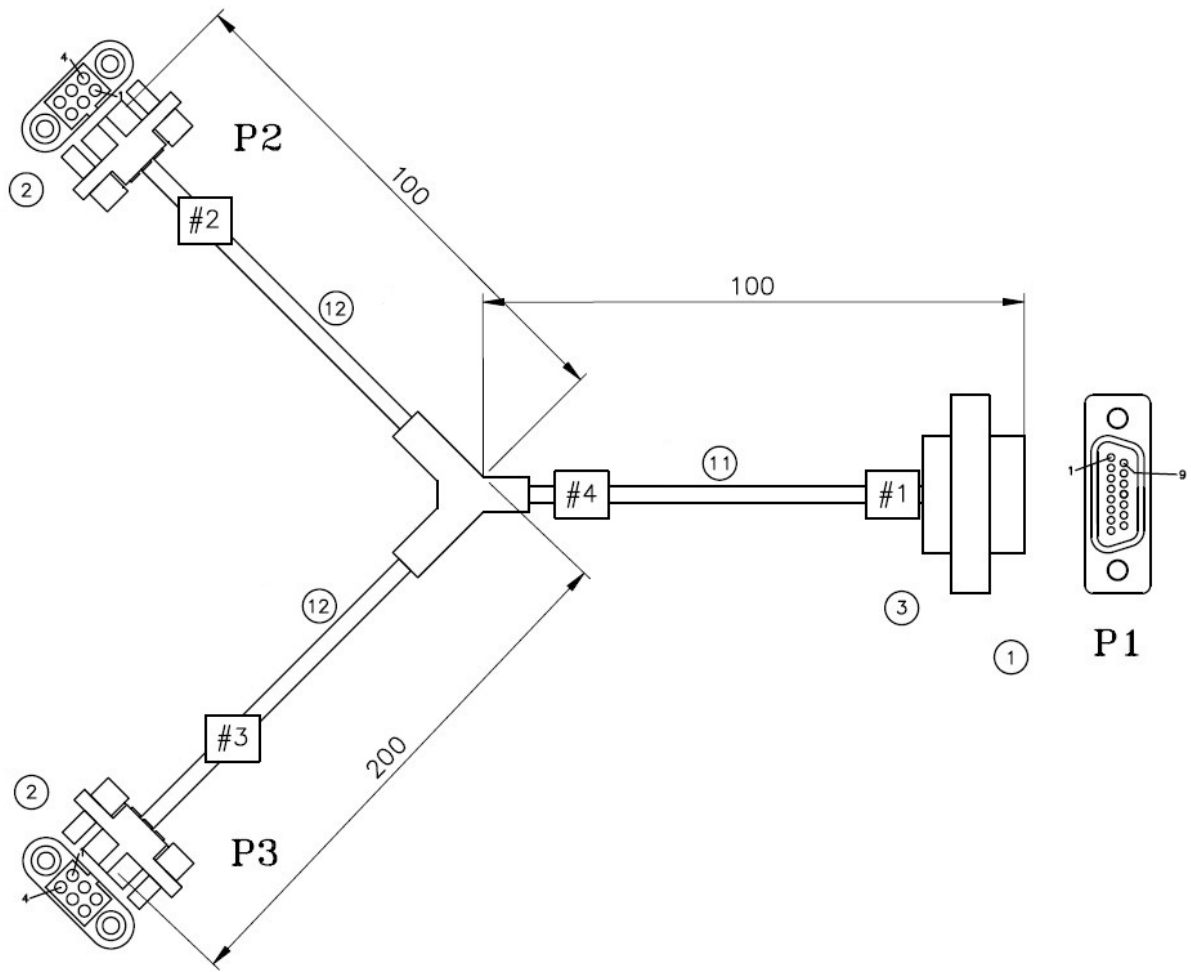


Figure 4.138 – W05/W06 plan

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	P1 – J2–RFCB	ITEM 8
#2	P2 – J6–MMCM2	ITEM 7
#3	P3 – J6–MCCM1	ITEM 7
#4	DETALLE "A"/DETAIL "A"	ITEM 8

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	P1 – J3–RFCB	ITEM 8
#2	P2 – J7–MMCM2	ITEM 7
#3	P3 – J7–MCCM1	ITEM 7
#4	Detalle "A"/Detail "A"	ITEM 8

Figure 4.139 – W05 and W06 label

The labels on the left correspond to those of the W05, and the labels on the right correspond to those of the W06.

Once the distances and connectors are known, the next step is to choose the amount of wire. In this cable, the PINOUT will not be placed either, but it is known that the signals coming out of P1 will be distributed between P2 and P3, so, from the 15 pins that P1 has, it will end up in 12 pins of the sum of P2 and P3. Therefore, the amount of conductor will be calculated, counting that there will be 15 wires, 7 of which will go to P2, and 8 will go to P3.

The type of wire to be used will be **AWG26**, since, as mentioned before in W03, the connector of P1 accepts the maximum thickness of this wire. Moreover, the information transmitted on this cable will be all communication signals, and not power signals, so there should not be any problem. Doing the corresponding calculations:

$$\text{AWG26 CONDUCTOR: } 7 * 200\text{mm} + 8 * 300\text{mm} = 1400 + 2400 = \mathbf{3800 \text{ mm}}$$

This cable is going to be the first one designed whose sleeve is not unique, as the cable has branches, three sleeves will have to be bought for each of the cable's sections. The first section, P1, will be the thickest, as it is the one that contains 15 wires, then the P2 section will have 7 wires, and the P3 section will have 8 wires. Applying the above formula used for the calculation of the sleeves, the following radiuses are obtained:

$$\text{P1 section radius} = \text{sqrt}(15 * 0.5 * 0.5) = \mathbf{1.93}$$

$$\text{P2 section radius} = \text{sqrt}(7 * 0.5 * 0.5) = \mathbf{1.32}$$

$$\text{P3 section radius} = \text{sqrt}(8 * 0.5 * 0.5) = \mathbf{1.41}$$

With the obtained radiuses, the sleeves to be used can be calculated in the same way as calculated for W01:

RAMAL	DIAMETER	BRAIDED SLEEVING	LENGTH
P1	3.87	GRP-110-1/4	0.1
P2	2.64	GRP-110-1/8	0.1
P3	2.82	GRP-110-1/8	0.2

This radius will also be used to choose the labels used on the cable, and therefore the following dimensions are chosen for each of the labels:

LABEL	MODEL	QUANTITY
ITEM 7	TMS-SCE-2X-1K-1/8	2
ITEM 8	TMS-SCE-2X-1K-1/4	2

#### 4.4.2.1.4 W08

The W08 cable will be responsible for powering the MCCM DUMMYS in a line, and will connect them to W01. As this cable will be responsible for powering the MCCM DUMMYS, it should have one connector for each board, and as there are 12 MCCM DUMMYS in a line, W08 will have 12 connectors that will be responsible for powering the boards. At the other extreme, there will be the connector that is going to get the power from W01, and distribute it through the wires that will supply it to the connectors on the boards.

The extreme of W08 that is connected to W01 will be P1, and it will be easy to find the corresponding connector, as it is the same as the one chosen for the P1.c. connector of W01, which was the opposite of the P2.c. of W01, which is where W08 has to fit. Therefore, this connector will be the next one:

### Conector D-sub HARTING, paso 2.29mm, Recta D-Sub de alta densidad, Montaje de Cable, Macho, Terminación Soldador B, 2.0A



Código RS: 923-0531 | N° ref. fabric.: 09563005604 | Fabricante: HARTING





Precio unitario (En una caja de 100)

**3,978 €**  
(exc. IVA)

**4,813 €**  
(inc. IVA)

unidades	Por unidad	Por Caja*
100 - 100	3,978 €	397,80 €
200 +	3,381 €	338,10 €

\*precio indicativo

unidades

Añadir

Figure 4.140 – W08 P1 connector

The extremes that go to the MCCM DUMMYS will be numbered from P2 to P13, and will all be the same connectors. These connectors will fit the J5 interface of the boards, which corresponds to the **221Y10F21** connector. Searching the **NICOMATIC** website, and setting the filters by gender, clamping, and mounting, the model **222S10M16** is obtained, which has the following appearance, and whose unit price is the following one:

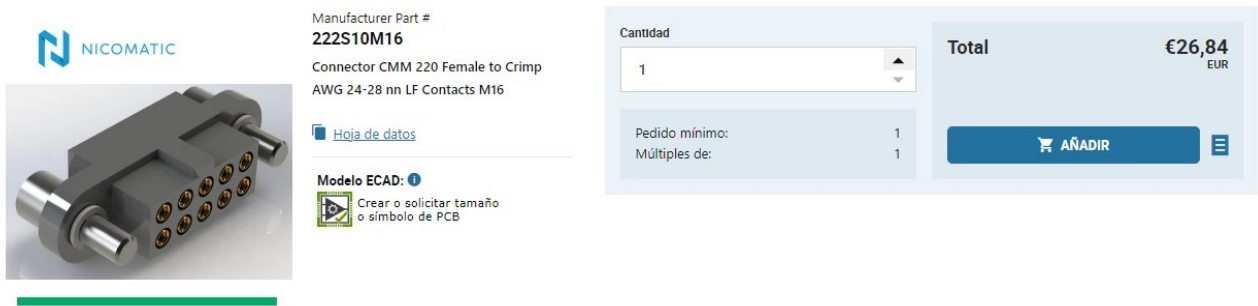


Figure 4.141 – W08 P2 connector

Once the connectors are found, the design of the plan is started, which will be an initial section leaving from P1, and at 400mm it will divide into 6 sections, one for RFCB, from which two other sections of 300mm and 150mm each will leave, depending on whether it goes to the first MCCM DUMMY, or the second one. At the end of each of these sections, the connectors that will go to the boards will be located. The plan would be sketched as follows:

#	TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	P1 -- TO P2.C.--W01_EXT	ITEM 10
#2	P2 -- TO J5--MCCM_1	ITEM 9
#3	P3 -- TO J5--MCCM_2	ITEM 9
#4	P4 -- TO J5--MCCM_3	ITEM 9
#5	P5 -- TO J5--MCCM_4	ITEM 9
#6	P6 -- TO J5--MCCM_5	ITEM 9
#7	P7 -- TO J5--MCCM_6	ITEM 9
#8	P8 -- TO J5--MCCM_7	ITEM 9
#9	P9 -- TO J5--MCCM_8	ITEM 9
#10	P10 -- TO J5--MCCM_9	ITEM 9
#11	P11 -- TO J5--MCCM_10	ITEM 9
#12	P12 -- TO J5--MCCM_11	ITEM 9
#13	P13 -- TO J5--MCCM_12	ITEM 9
#14	Detalle "A"/Detail "A"	ITEM 10

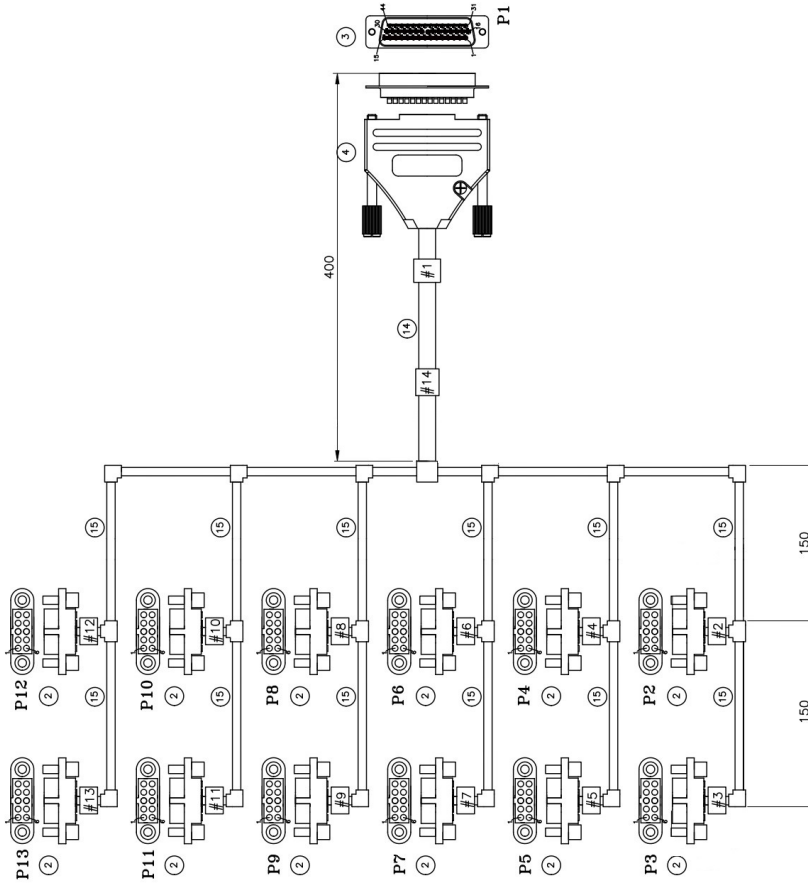


Figure 4.142 – W08 plan and labels

To calculate the quantity of wire, it starts by calculating the section from the intersection to connector P1. This section will be 400mm long, and will have 44 **AWG22** wires, one for each pin. This will give  $400\text{mm} \times 44 = 17600\text{mm}$  of **AWG22** wire for the first section.

To calculate the remaining quantity of wire required, it will be calculated the quantity of wire required for a single section, and multiplied by six, which is the number of sections from the intersection to the MCCMs. Each section, in turn, will have two sections, one of 150mm, and one of 300mm. Ten **AWG22** conductors will run along each of these small sections, giving a quantity of wire per section of  $(10 \times 300\text{mm}) + (10 \times 150\text{mm}) = 4500\text{mm}$ . Multiplying this figure by the six sections of the cable gives  $4500\text{mm} \times 6 = 27000\text{mm}$ .

Adding the quantities of wire **AWG22** from the sections going to the MCCMs, and the section going to P1, gives the following quantity:  $27000\text{mm} + 17600\text{mm} = 44600\text{mm}$  of **AWG22** wire.

The next step is to calculate the sleeves and labels that will go on each of the sections. As the PINOUT is not going to be shown, and, following the drawing, the cable would go from 44 pins of P1 to 120 pins of the sum of the connectors of the MCCM DUMMYS, it will be assumed that the soldering corresponding to this increase in pins will be done near P1. In this way, the 120 wires that reach the connectors of the boards will pass through the section of P1. To the rest of the sections, as 10 wires will arrive, only these will be taken into account to calculate the sleeve. Making the corresponding calculations:

$$\begin{aligned} \mathbf{P1\ RADIUS} &= \text{sqrt}(120 * 0.64 * 0.64) = \mathbf{7.01} \\ \mathbf{EVEN\ CONNECTORS\ RADIUS} &= \text{sqrt}(10 * 0.64 * 0.64) = \mathbf{2.02} \\ \mathbf{ODD\ CONNECTORS\ RADIUS} &= \text{sqrt}(10 * 0.64 * 0.64) = \mathbf{2.02} \end{aligned}$$

From these measurements, the sleeves and labels to be used are obtained by looking at the tables in the annexes.

RAMAL	DIAMETER	BRAIDED SLEEVING	LENGTH
P1	14.02	GRP-110-3/4	0.4
EVEN CON.	4.04	GRP-110-1/8	0.15
ODD CON.	4.04	GRP-110-1/8	0.3

With the radiuses calculated above, the labels are also chosen, which, as seen in the label identification table of the cable plan, will be of two types:


LABEL	MODEL	QUANTITY
ITEM 9	TMS-SCE-2X-1K-1/4	12
ITEM 10	TMS-SCE-2X-1K-3/4	2

For this cable, in addition, as can be seen in the drawing, a backshell for P1 will be

included, since as it is connected to the W01, it will be constantly connecting and disconnecting. This backshell was already selected during the design of the W01, so the same model will be included.

## Carcasa de conector D-sub SérieMHDTZK-RA, Recta, 25 contactos Zinc, Plateado, B

Código RS: 460-979 | N° ref. fabric.: MHDTZK25-RA-PC-K | Fabricante: MH Connectors



19314 Disponible para entrega en 24/48 horas

Precio Unidad  
**6,23 €** (exc. IVA) **7,54 €** (inc. IVA)

unidades	Por unidad
1 - 24	6,23 €
25 - 99	5,43 €
100 - 249	5,35 €
250 - 499	4,64 €
500 +	4,43 €

unidades

Añadir

Figure 4.143 – W08 Backshell

### 4.4.2.1.5 W50

This cable will be the last of the external cables, and its function will be to program the cores of the MCCM DUMMYs. This cable will only be connected when it is necessary to change some of the code stored in these cores, and therefore it will not be permanently connected.

The extremes of this cable will be two, one of them will be a connector that will fit with the J3 interface of the MCCM DUMMY, and will be named P1; and the other extreme, will be 4 connectors, one for each core, and numbered from P2 to P5, which will be connected to a programmer of the company.

As the extreme P1, will have to connect to the J3 interface of the MCCM, it means that it will have to fit with the 40-pin, two-row male connector manufactured by **SAMTEC**. Therefore, P1 will be the 40-pin, two-row female connector manufactured by **SAMTEC**, which can be seen in the picture below:



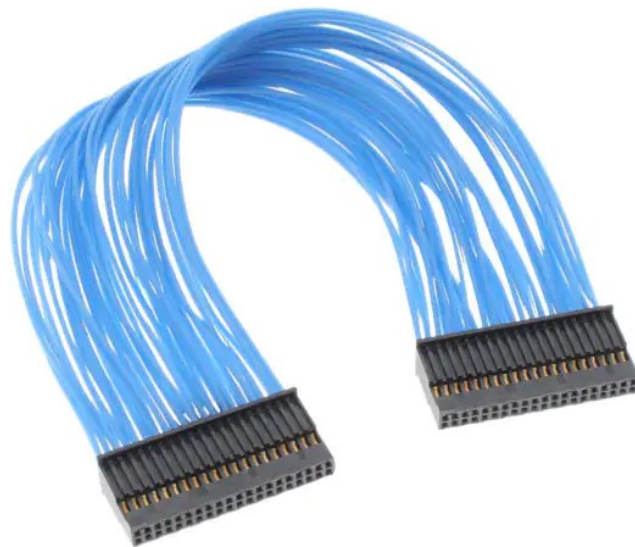


Figure 4.144 – W50 P1 connector

The connector comes with the cable and with another connector at the opposite extreme, so what will be done, will be to buy it complete, and cut it in half. This way, by measuring the cable 180mm, there will be two connectors like the ones wanted with a 90mm cable included. The price of this cable through the distributor **DIGIKEY** is **17.97€** as can be seen in the following picture:





**SFSDT-20-28-G-07.00-D-NDX** [Hoja de datos](#)

Número de pieza de Digi-Key: 612-SFSDT-20-28-G-07.00-D-NDX-ND  
 Fabricante: **Samtec Inc.**  
 Número de pieza del fabricante: SFSDT-20-28-G-07.00-D-NDX  
 Descripción: .050 (1.27) SOCKET DISCRETE CABL  
 Plazo estándar del fabricante: 9 semanas  
 Descripción detallada: Ensamblajes de cable rectangular  
 Referencia del cliente:

**Precio y compra**

CANTIDAD

Agregar al carrito

ESCALA DE PRECIOS	PRECIO UNITARIO	PRECIO TOTAL
1	17,97000	€17,97
10	16,21800	€162,18
25	15,53840	€388,46
50	14,56720	€728,36

Figure 4.145 – W50 P1 connector price

At the other extreme, there will be the connectors that fit the programmer, which is an **ATMEL** model with an interface compatible with JTAG cables. The JTAG cables have at each extreme a rectangular connector with a polariser, and whose contacts are distributed in two rows. These cables can have different numbers of contacts, but the ones that will be used for this cable will have 10 contacts, like the one shown in the following image:



Figure 4.146 – W50 P2-P5 connector

4

As a pin-to-pin cable is included in the purchase, what will be done with this cable is the same as with the previous one, it will be cut in half, and in this way, it will be possible to obtain two connectors like the ones wanted. This cable, which is 150mm long, meaning 75mm per connector, can also be purchased from the distributor **DIGIKEY** for **11.69€**:



**TCSD-05-D-06.00-01-N** [Hoja de datos](#)

<b>Número de pieza de Digi-Key</b>	SAM8531-ND
<b>Fabricante</b>	Samtec Inc.
<b>Número de pieza del fabricante</b>	TCSD-05-D-06.00-01-N
<b>Descripción</b>	CABLE ASSEM 2MM 10POS F-F 6"
<b>Plazo estándar del fabricante</b>	9 semanas
<b>Descripción detallada</b>	10 Ensambls de cable rectangular Enchufe a enchufe 0.500" (152.40mm, 6.00")
<b>Referencia del cliente</b>	<input type="text" value="Referencia del cliente"/>

**Precio y compra**

**CANTIDAD**

Agregar al carrito

ESCALA DE PRECIOS	PRECIO UNITARIO	PRECIO TOTAL
1	11,69000	€11,69
10	10,36300	€103,63
25	9,96400	€249,10
50	9,56540	€478,27

Figure 4.147 – W50 P2-P5 connector price

Now the distance between both connectors is calculated, and, as with the W03, as it is a cable that will be used in specific situations, it will be a short cable. Taking advantage of the fact that the connectors come with a cable included, this will be used to manufacture the cable, and therefore, a distance between connectors of 150mm will be chosen. Drawing the plan corresponding to the cable, the following drawing is obtained:

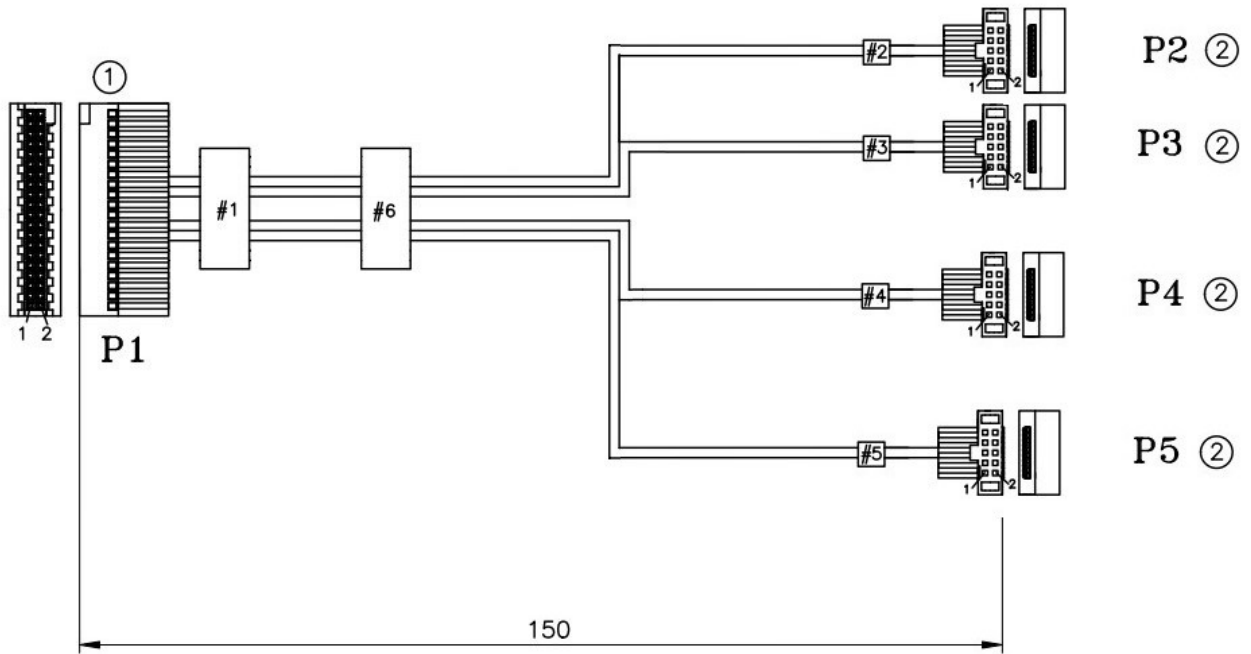


Figure 4.148 – W50 Plan



TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	P1 J3 MCCM DUMMY	ITEM 6
#2	P2 JTAG 1	ITEM 5
#3	P3 JTAG 2	ITEM 5
#4	P4 JTAG 3	ITEM 5
#5	P5 JTAG 4	ITEM 5
#6	Detalle "A"/Detail "A"	ITEM 6

Figure 4.149 – W50 labels

As already mentioned, there is no need to buy more cable, as the one included in the connectors is sufficient. This cable, in spite of being external, will not have a sleeve either, as, in addition to being too short to use one, it is made up of a strip of wires that are all joined together, so the function of the sleeve would not be necessary.

As for the labels, the conventional labels that are used on all cables will not be used, as the PVC covering of the cables, and the use of heat guns to retract the labels, can damage the cable. In addition, the flat shape of the cable strip means that it does not conform to the cylindrical shape of the labels. Therefore, for this cable, adhesive labels like the ones on W03 should be used, as they adapt better to any surface and are ideal for this type of case.

#### 4.4.2.2 CABLES INT

The internal cables will be all those that are inside the rack, and therefore will be responsible for connecting the different parts that compose it. These cables, once they are installed, will not be manipulated, so it will not be necessary to look for sleeves to keep the wires together, but it will be necessary to look for labels to identify where each cable has to be installed. In the event that some of the internal cables are very long, and it is difficult to keep the wires together, black string can be used to tie them at some points of the cable, and in this way keep it a little more compact. These cables, also, will not always have a defined length, since, being inside the rack, and not knowing where they will have to pass through, the exact length of these cables will not be known, and this will be defined at the time of manufacturing them. Meanwhile, in the cables that are not defined, the length will be TBD (To Be Determined), and it will be decided later. The cables that belong to this section are:

- W09
- W10
- W11
- W12
- W13
- W15
- W34

##### 4.4.2.2.1 W09

This cable will be responsible for transmitting and receiving information from the EIM BOARD to the climatic chamber in case it is used for testing. The cable will connect the J4 interface of the EIM BOARD to the front of the EIM BOX.

The J4 interface of the EIM BOARD is a **NICOMATIC** connector with serial number **102Y02**, so it will be necessary to search on the website for one that fits this one. Applying the necessary filters, the **101C02L** model is obtained, which would fit the J4 interface of the EIM BOARD.

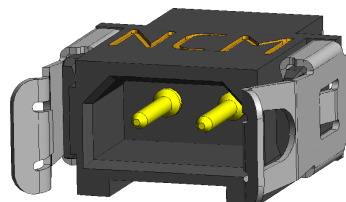


Figure 4.150 – W09 J4 connector

The other extreme of the W09, which will have to fit with the cable coming from the thermal camera, will be the **IMC24-1602X** connector from the company **DEUTSCH**, which is available from **RS Component** at the following price:

**Carcasa Deutsch hembra serie IMC de 2 vías macho a hembra, tamaño carcasa 2, Montaje en Panel, IP67** 

Código RS: 314-6799 | N° ref. fabric.: IMC24-1602X | Fabricante: [Deutsch](#)




25 Disponible para entrega en 24/48 horas

Precio Unidad

**9,74 €** **11,79 €**  
(exc. IVA) (inc. IVA)

unidades	Por unidad
1 - 9	9,74 €
10 - 49	8,78 €
50 - 99	7,91 €
100 - 249	7,11 €
250 +	6,39 €

−
1
+
unidades

**Figure 4.151** – W09 P1 connector

Once the connectors have been chosen, the next step is to calculate the distance, and, although it had been said that for most cases of internal cables there would not be a defined distance, in this case, as it is a simple cable that goes from the EIM BOARD to the front panel, it will only be necessary to estimate the distance between these two points.

By looking at the sketch made during the selection of the EIM BOX sources, where the lengths of both the base of the EIM BOX and the EIM BOARD are delimited, and, knowing that the J4 connector of the EIM BOARD will be on the left side of the board, a little above the middle of the board, it can be deduced that 300mm of cable length will be enough to keep the cable without it being tense, and without having so much cable that it bothers.



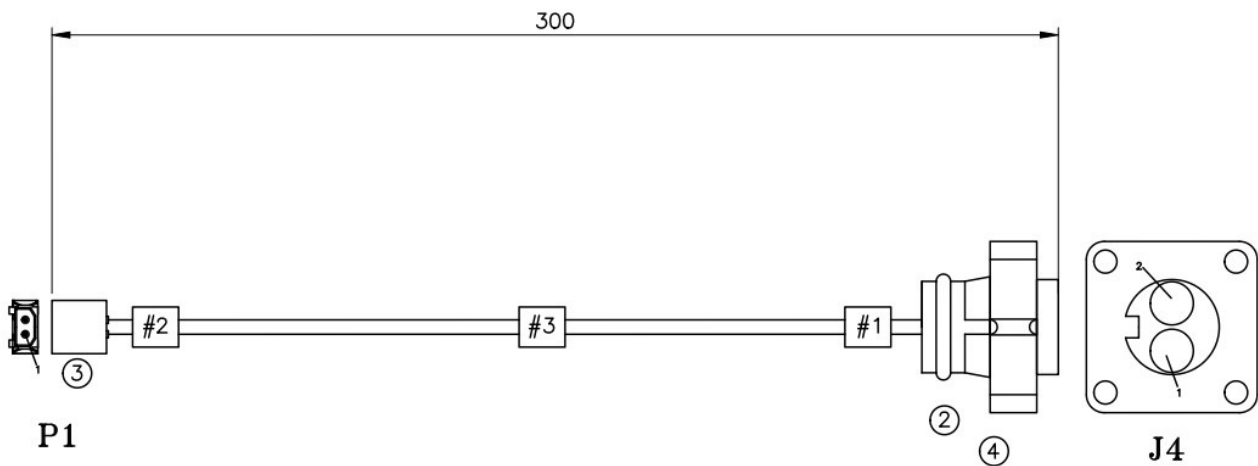


Figure 4.152 – W09 plan

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	J4 – TO P1–EIM_BOX	ITEM 7
#2	P1 – TO J4–EIM_BOARD	ITEM 7
#3	Detalle "A"/Detail "A"	ITEM 7

Figure 4.153 – W09 labels

Looking at the datasheets of both connectors, it is possible to observe that both accept **AWG22**, so this type of cable will be chosen for the manufacture. As there are only two wires, whose length will be 300mm, the calculations will be easy, as only 600mm of **AWG22** wire will be needed.

As stated at the beginning of this section, this cable will not have a sleeve over it, but it will have labels. Knowing that **AWG22** has a radius of 0.64mm, the corresponding calculations are made:

$$\text{W09 RADIUS} = \text{sqrt}(2 * 0.64 * 0.64) = \mathbf{0.9\text{mm}}$$

The radius of 0.9mm assumes a diameter of 1.8mm, and looking at the tables, three labels are chosen from the smallest size model, which is **TMS-SCE-2X-1K-3/32**.

4.4.2.2.2 W10

The W10, will be the cable that is responsible for transmitting the communication signals between the EIM BOARD and the front end of the EIM BOX. The extreme of the cable that goes to the EIM BOARD, P1, could be connected either to the J1 interface, or to the J2 interface. As seen in the board design section, both interfaces are fitted with a **NICOMATIC** connector whose model is **321YL120F44H**. Searching on the French company’s website, a compatible model is available, whose serial number is **322C120H01**.

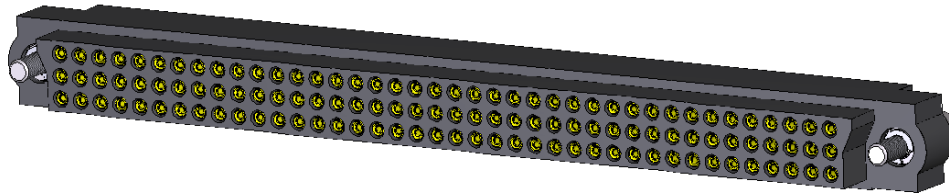


Figure 4.154 – W10 P1 connector

The other extreme of the cable, will be placed in the front of the EIM BOX, and will fit with the W01, specifically with the P1.a. and P1.b. interfaces. As the W10 connectors must be able to fit with those of P1.a. and P1.b. of the W01, the opposite connectors are searched for, which match with the P2.a. and P2.b. interfaces of the W01. In this way, the following connectors are obtained, for interfaces J1.a. and J1.b. of W10 respectively:

**Conector D-sub HARTING, paso 2.42mm, Recta D-Sub de alta densidad, Montaje de Cable, Hembra, Terminación Soldador C,**



Código RS: 923-0516 | Nº ref. fabric.: 09564004704 | Fabricante: HARTING

50 Disponible para entrega en 24/48 horas

Precio unitario (En una caja de 50)

6,382 €

(exc. IVA)

7,722 €

(inc. IVA)

unidades	Por unidad	Por Caja*
50 - 50	6,382 €	319,10 €
100 +	5,425 €	271,25 €

\*precio indicativo

–
50
+
unidades

Añadir

Figure 4.155 – W10 J1.a. connector



**Conector D-sub HARTING, paso 2.42mm, Recta D-Sub de alta densidad, Montaje de Cable, Macho, Terminación Soldador C, 2.0A** 

Código RS: 923-0540 | Nº ref. fabric.: 09564005604 | Fabricante: HARTING



50 Disponible para entrega en 24/48 horas

Precio unitario (En una caja de 50)  
**5,735 €** (exc. IVA)      **6,939 €** (inc. IVA)

unidades	Por unidad	Por Caja*
50 - 50	5,735 €	286,75 €
100 +	4,875 €	243,75 €

\*precio indicativo

50  unidades

Añadir

Figure 4.156 – W10 J1.b. connector

Now that the connectors have been selected, the next step is to draw the plane, which will not have a fixed measurement, since depending on the interface of the EIM BOARD, the cable will measure more or less. In this way, it is defined as TBD, and the measurement will be chosen later, when the appropriate length can be accurately measured.

4

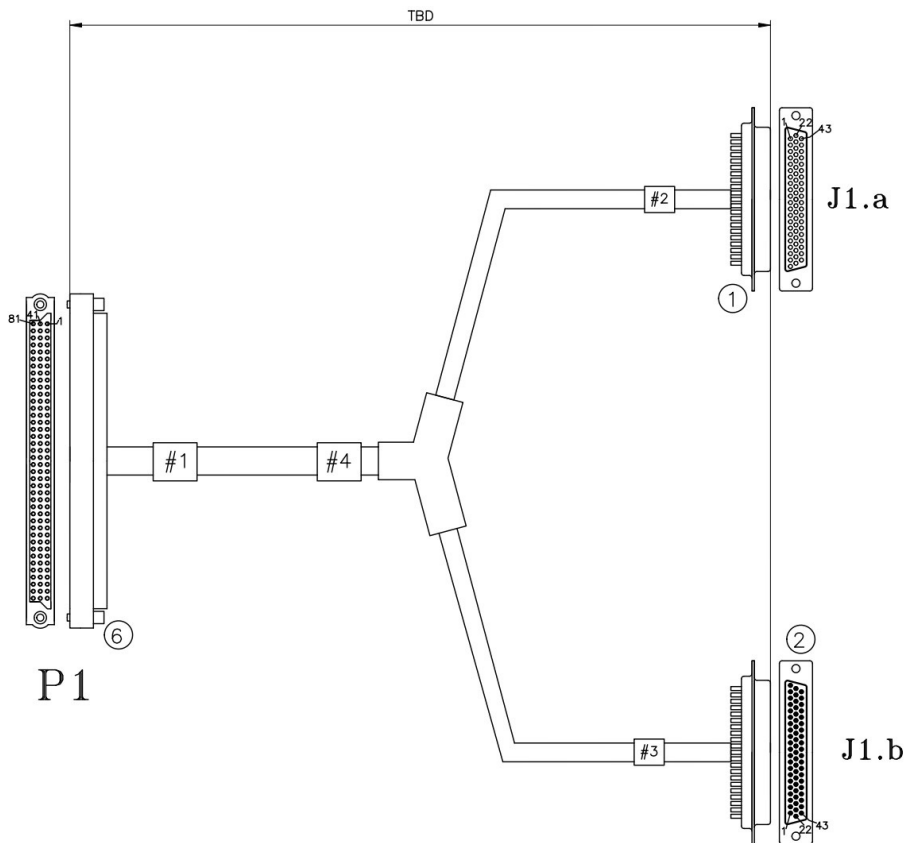


Figure 4.157 – W10 plan



TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	P1 - FROM J1/J2-EIM_BOARD	ITEM 16
#2	J1.A./J2.A. - TO P1.A./P2.A.-EIM_BOX	ITEM 16
#3	J1.B./J2.B. - TO P1.B./P2.B.-EIM_BOX	ITEM 16
#4	Detalle "A"/Detail "A"	ITEM 16

Figure 4.158 – W10 labels

Since the length of the cable will not be defined, it is not possible to calculate precisely how much cable will be needed. Therefore, an estimate will have to be made at a high level, so that there will be no shortage of cable. As seen in the design of the W01, the cable used for the transmission of these signals will be **AWG26**, and, making an approximation of the necessary length of the cable so that it can be connected without tension, a length of 300mm is assumed, which should be sufficient distance for the cable to be able to arch and stay connected without stress, since the connectors J1 and J2 of the EIM BOARD are no more than 150mm away from the front of the EIM BOX.

The quantity of wires needed for this cable will correspond to the extreme with the highest number of pins. At the P1 end, there is only one connector with 120 pins, while at the J1 end, there are two connectors with 62 pins each, meaning 124 in total. Therefore, the cable will be considered to have 24 wires, and making the appropriate calculations:

$$\text{AWG 26 CONDUCTOR} = 124 * 300\text{mm} = \mathbf{37200 \text{ mm}}$$
 of AWG 26 wire.

Now, it only remains to find the labels that fit the width that the cable will have, which will be different according to the section. For sections J1.a. and J1.b., the same labels will be used, while for the P1 section, possibly larger ones will be used. Taking into account the use of wires of AWG 26 with thickness 0.5, the following diameters will be obtained:

$$\text{P1 RADIUS} = \text{sqrt}(120 * 0.5 * 0.5) = \mathbf{5.47} \quad \text{J1 RADIUS} = \text{sqrt}(62 * 0.5 * 0.5) = \mathbf{3.94}$$

LABEL	DIAMETER	MODEL	QUANTITY
ITEM 9	10.94	TMS-SCE-2X-1K-3/4	12
ITEM 10	7.87	TMS-SCE-2X-1K-1/2	2



#### 4.4.2.2.3 W11

This cable will be responsible for distributing the power from the rack sources to the front of the EIM BOX, where it will connect to the W01. It will also have two extremes, the left extreme, with connectors numbered P1 to P6, and the right extreme, with three connectors numbered J1.d., J1.e., and J1.f.

The right extreme will be the one that will be fitted to the front of the EIM BOX, and therefore, the one that will be connected to the W01. The W01 interfaces to which it will be connected are P1.d., P1.e., and P1.f., and as we already know, the connectors that fit in these are the same as the ones already selected for P2.d., P2.e., and P2.f. Therefore, the connectors for interfaces J1.d., J1.e., and J1.f. of the W11 cable will be the same as those for interfaces P2.d., P2.e., and P2.f. of W01.

At the other extreme, the interfaces will correspond to the rack power supplies, which distribute power from a removable connector, where the cables are connected from a screw. The connector for these power supplies is a model like the one shown below, which has two contacts to supply the power and its return, and two other sensing contacts that will help to maintain the voltage and current at the set values.



**Figure 4.159** – *Power supplies connector*

As there will be 3 source mainframes, with 4 source modules each, there will be a total of 12 connectors as the one shown in the picture, of which 6 will be for one line, and 6 for the other. Therefore, the W11 cable will distribute the power transmitted to the DB from six 4-pin connectors to two 78-pin connectors and one 26-pin connector. As these cables will go from the front of the EIM BOX to the sources passing through the inside of the EIM BOX, and through the back of the rack, the exact length of the cable will not be known, so, in this case, TBD is used again, leaving the plan as follows:

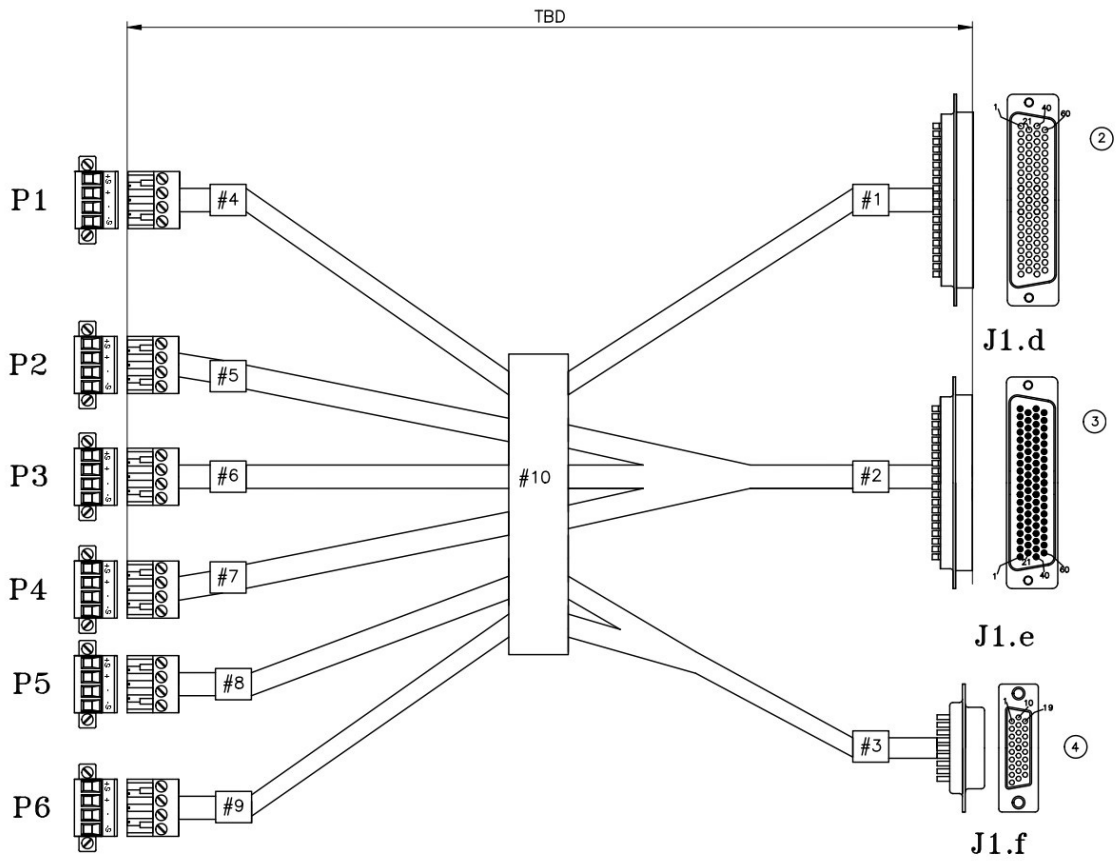


Figure 4.160 – W11 plan

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	J1.D./J2.D. – P1.D./P2.D.–EIM_BOX	ITEM 15
#2	J1.E./J2.E. – P1.E./P2.E.–EIM_BOX	ITEM 15
#3	J1.F./J2.F. – P1.F./P2.F.–EIM_BOX	ITEM 16
#4	P1 – PS_UNIT3_VDD_MCCM_N6742B	ITEM 17
#5	P2 – PS_UNIT3_VDD_SC_N6732B	ITEM 17
#6	P3 – PS_UNIT1_VG_SSPA_N6733B	ITEM 17
#7	P4 – PS_UNIT1_VDD_LNA_N6732B	ITEM 17
#8	P5 – PS_UNIT2_FLOAT_GND_SYS_N6732B	ITEM 17
#9	P6 – PS_UNIT2_VCC2_N6732B	ITEM 17
#10	DETALLE A/DETAIL A	ITEM 18

Figure 4.161 – W11 labels

As can be seen in the drawing, not all the connectors on J1 will have the same number of source connectors. This is because, as the sources will not supply the same amount of current, they will need different numbers of wires to be distributed without burning the conductor, and therefore different numbers of pins for the connectors.

Repeating what has been said before, the power supply connectors will have 4 contacts, of which only 2 will be for supplying the power. In these contacts only one wire will be able to enter, therefore, all the conductors through which the power from one of the sources circulates will have to be joined together in a single wire, and as mentioned at the beginning of the TBT section, for these cases, an **AWG 16** or an **AWG 14** will be used, obtaining the following conductors:

- **VDD\_MCCM = 9.076 A : AWG14**
- **VDD\_SC = 4.66 A : AWG16**
- **VDD\_LNA = 2.664 A : AWG16**
- **VG\_SSPA = 0.396 A : AWG16**
- **VSS = 0.612 A : AWG16**
- **VCC2 = 0.756 A : AWG16**

Although it is not possible to know the exact length of the cable, it is possible to estimate the length of the cable in the same way as has been done for other cables. It is known that this cable will start at the front of the EIM BOX, go through the entire box, and connect at the back to the rack sources, so it can be assumed that the cable will necessarily be longer than the length of the EIM BOX, which is 483mm, which could be rounded up to 500mm. Once it leaves the EIM BOX, the distance to the sources will depend on which of these it goes to, so it is not possible to know exactly what the total length will be. For this purpose, in order to guarantee the correct length of the cable, and knowing that it should measure at least 500mm, all the necessary soldering will be done before this distance, and from this distance onwards the cable will be formed only by the corresponding wire with a length of 300mm that will go to the sources. This will make the cable 800mm long, with the possibility of cutting the last wire until the cable is 500mm long. In this way, the cable is allowed to adapt to the length needed to be able to connect to each of the sources, without being too tight or too baggy.

Therefore, before 500mm of cable, all the wires will be **AWG22**, which is the wire that fits the J1 connectors, and after 500mm, the wires will be **AWG16** or **AWG14**, as appropriate. It should be noted that for each source connector there will be two sensing wires, so these will be given a length of 800mm directly.

As the VDD\_MCCM source transmits so much current through J1.d., it will have to be divided into 78 **AWG22** wires, which will be 38 for the positive pole, 38 for the negative

pole, 1 for the positive sense, and 1 for the negative sense. As it is very difficult to make a solder that converts 38 **AWG22** wires into one **AWG14** wire, this will be done in two steps.

First, these conductors will be divided into two groups of 19 **AWG22** conductors, which will each be converted into one **AWG16** conductor, and then the two **AWG16** conductors will be soldered to one **AWG14** conductor. The **AWG22** part will be made to match the rest of the cable, meaning 500mm, and then the **AWG16** conductors will be cut to a length of 100mm, leaving 200mm for the **AWG14** conductor.

Making the corresponding calculations for each of the cable thicknesses, the following is obtained:

POWER SUPPLY	AWG 22 WIRES	QUANTITY(MM)
VDD_MCCM	76 wires * 500 mm + 2 wires * 800mm	39600
VDD_SC	40 wires * 500mm + 2 wires * 800mm	21600
VDD_LNA	24 wires * 500mm + 2 wires * 800mm	13600
VCC (VSS)	10 wires * 500mm + 2 wires * 800mm	6600
VCC2	12 wires * 500mm + 2 wires * 800mm	7600
Vg_SSPA	8 wires * 500mm + 2 wires * 800mm	5600
<b>TOTAL</b>		<b>94600</b>

$$\text{AWG22 WIRE} = 94600 \text{ mm}$$

POWER SUPPLY	AWG 16 WIRE	QUANTITY (MM)
VDD_MCCM	2 wires * 100mm	200
VDD_SC	1 wires * 300mm	300
VDD_LNA	1 wires * 300mm	300
VCC (VSS)	1 wires * 300mm	300
VCC2	1 wires * 300mm	300
Vg_SSPA	1 wires * 300mm	300
<b>TOTAL</b>		<b>1700</b>

$$\text{AWG16 WIRE} = 1700 \text{ mm}$$

$$\text{AWG14 WIRE} = 200 \text{ mm}$$

Now, focusing on the labels, the ones from 4 to 9, item 17, will be responsible for grouping only 4 cables. Labels 1 and 2, item 15, will be responsible for grouping 78 wires of **AWG22**. And 3, item 16, will be responsible for grouping only 26 wires of **AWG22**. Calculating the radiuses for these labels:

$$\text{ITEM 15 RADIUS} = \text{sqrt} (78 * 0.64 * 0.64) = \mathbf{5.65}$$

$$\text{ITEM 16 RADIUS} = \text{sqrt} (26 * 0.64 * 0.64) = \mathbf{3.26}$$

$$\text{ITEM 17 RADIUS} = \text{sqrt} ((2 * 0.64 * 0.64) + (2 * 1.05 * 1.05)) = \mathbf{1.74}$$



LABEL	DIAMETER	MODEL	QUANTITY
ITEM 15	11.30	TMS-SCE-2X-1K-3/4	1
ITEM 16	6.52	TMS-SCE-2X-1K-3/8	2
ITEM 17	3.48	TMS-SCE-2X-1K-3/16	6

#### 4.4.2.2.4 W12

The W12 will be a cable that will be responsible for connecting the EIM BOARD to the control interfaces of the sources inside the EIM BOX, and will also connect the 5V and 3.3V sources to the EIM BOARD to power it for it to operate. This cable will have an extreme, P1, which will be the one that connects to the EIM BOARD, and from which the different ramifications that go to the sources inside the EIM BOX will be formed.

P1 will be the connector that fits into the J3 interface of the EIM BOARD, whose connector is a type D, micro D which has 25 male type contacts. To make it fit properly, it will be necessary to look for the opposite connector to this one, which will be a 25-pin female connector. Looking at the DIGIKEY website, it is possible to find the model MMDS-025-N00-SS-RH, which, as can be seen in the following image, would fit perfectly in the connector of the board.



Figure 4.162 – W12 P1 connector

This connector will have the following price on the DIGIKEY website



**MMDS-025-N00-SS-RH**

Número de pieza de Digi-Key: 2262-MMDS-025-N00-SS-RH-ND  
Fabricante: Omnetics  
Número de pieza del fabricante: MMDS-025-N00-SS-RH  
Descripción: CONN MICRO-D RCPT 25POS SLDR CUP  
Plazo estándar del fabricante: 8 semanas  
Descripción detallada: 25 Posiciones Tipo D, Micro-D Receptáculo, enchufes hembra Conector  
Referencia del cliente: Referencia del cliente

**Precio y compra**

CANTIDAD

Agregar al carrito

Agregar a la lista

Todos los precios están en EUR.

ESCALA DE PRECIOS	PRECIO UNITARIO	PRECIO TOTAL
1	176,78000	€176,78
10	163,81400	€1.638,14

Figure 4.163 – W12 P1 price

The rest of the terminals will be of two types, those that go to the control interface of the sources, and those that go to the voltage outputs of the sources. Those going to the source control interfaces will be numbered P2 to P5, one for each of the sources, and the connectors to be looked for will be, according to the datasheet, CN100 connectors.

**Mechanical Specification**

Case No.901I Unit:mm

Terminal Pin No. Assignment

Pin No.	Assignment	Pin No.	Assignment
1	AC/L	4,5	DC OUTPUT -V
2	AC/N	6,7	DC OUTPUT +V
3	FG $\pm$		

Connector Pin No. Assignment (CN100) :  
HRS DF11-6DP-2DSA or equivalent

Pin No.	Assignment	Mating Housing	Terminal
1	-S	HRS DF11-6DS or equivalent	HRS DF11-**SC or equivalent
2	+S		
3	AUXG		
4	AUX		
5	RC-		
6	RC+		

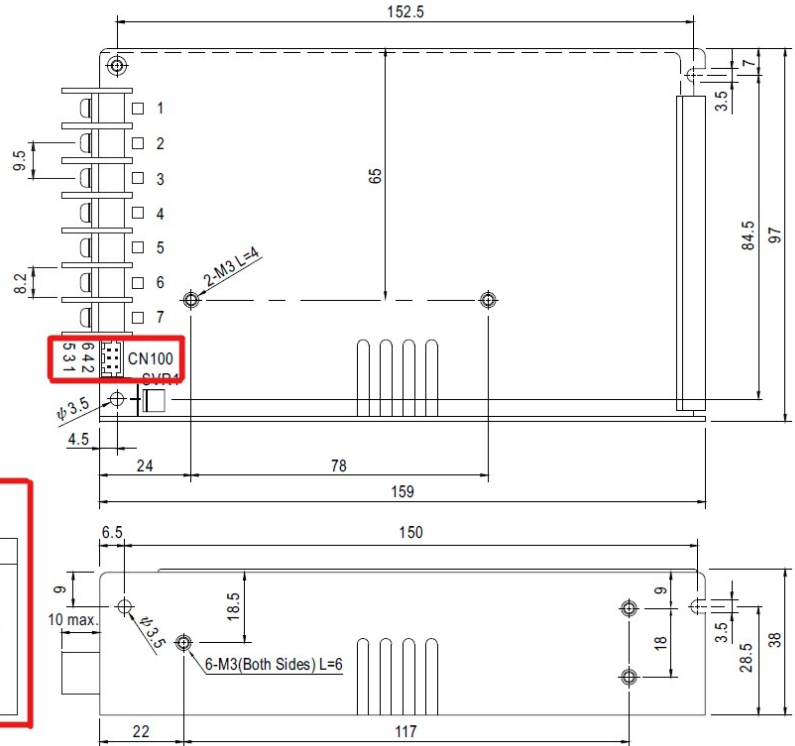


Figure 4.164 – HRPG-150 series datasheet

These connectors are available from the RS Component website, and are priced as follows:

## Carcasa de conector Hirose DF11-6DS-2C, Serie DF11, paso: 2mm, 6 contactos, 2 HRS filas, Recta, Hembra, Montaje de Cable

Código RS: 688-9095 | N° ref. fabric.: DF11-6DS-2C | Fabricante: Hirose



Precio unitario (Suministrado en múltiplos de 25)

**0,154 €** (exc. IVA) **0,186 €** (inc.IVA)

unidades	Por unidad	Por Pack*
25 - 475	0,154 €	3,85 €
500 - 1850	0,127 €	3,175 €
1875 - 7475	0,108 €	2,70 €
7500 - 14975	0,10 €	2,50 €
15000 +	0,092 €	2,30 €

\*precio indicativo

− 25 + unidades

Añadir

Figure 4.165 – CN100 connector price

4

To insert the conductors of the cable into the connector, it will be necessary to purchase pins which are available from the RS website, and which will have to be crimped to the ends of the conductors.

## Contacto de crimpado Hirose DF11-22SCA, DF11, Hembra, Crimpado, Revestimiento de Oro 22AWG 0.3mm<sup>2</sup>

HRS

Código RS: 111-3621 | N° ref. fabric.: DF11-22SCA | Fabricante: Hirose



16900 Disponible para entrega en 24/48 horas

Precio unitario (En una bolsa de 100)

**0,093 €** (exc. IVA) **0,113 €** (inc.IVA)

unidades	Por unidad	Por Bolsa*
100 - 1900	0,093 €	9,30 €
2000 - 7400	0,083 €	8,30 €
7500 - 29900	0,074 €	7,40 €
30000 - 59900	0,07 €	7,00 €
60000 +	0,065 €	6,50 €

\*precio indicativo

Figure 4.166 – CN100 pins price



As only the RC- and RC+ signals will be used out of the 6 possible signals, only two pins per connector will be purchased, meaning a total of 8 pins.

The other terminals that have to be found are the ones that will go to the outputs of the 5V and 3.3V sources, which, as it can be seen in the datasheet image, correspond to interfaces 4, 5, 6, and 7 of the sources. These interfaces are formed by a screw that is responsible for holding the terminal to be inserted. These terminals can be of different types and sizes, but the one that will be used in this case will be fork terminals whose width will be a maximum of 8.2mm, which is the separation between the walls of the interfaces. In **RS Components** website is possible to find forks that fit perfectly, such as the following one, whose width will be 5.7mm, and whose price will be as follows:

**Terminal de horquilla Phoenix Contact, Serie C-FCI 2.5/M3.5, Aislado, M3.5, Azul No Recubierto, 1.5mm<sup>2</sup> a 2.5mm<sup>2</sup>**

Código RS: 804-6962 | N° ref. fabric.: 3240038 | Fabricante: Phoenix Contact

**993 Disponible para entrega en 24/48 horas**

Precio Unidad  
**0,27 €** (exc. IVA)      **0,33 €** (inc. IVA)

unidades	Por unidad
1 - 4	0,27 €
5 - 24	0,25 €
25 - 49	0,24 €
50 - 74	0,23 €
75 +	0,21 €

- 1 + unidades

**Figure 4.167** – Fork terminals

For this cable it will be necessary to buy 8 forks of this type, 4 per source, and this model will also be used later for other cables.

Once the connectors are ready, the next step is to design the drawing, in which the cable length will be TBD, because it will not be possible to know the exact distances until the whole EIM BOX is assembled.



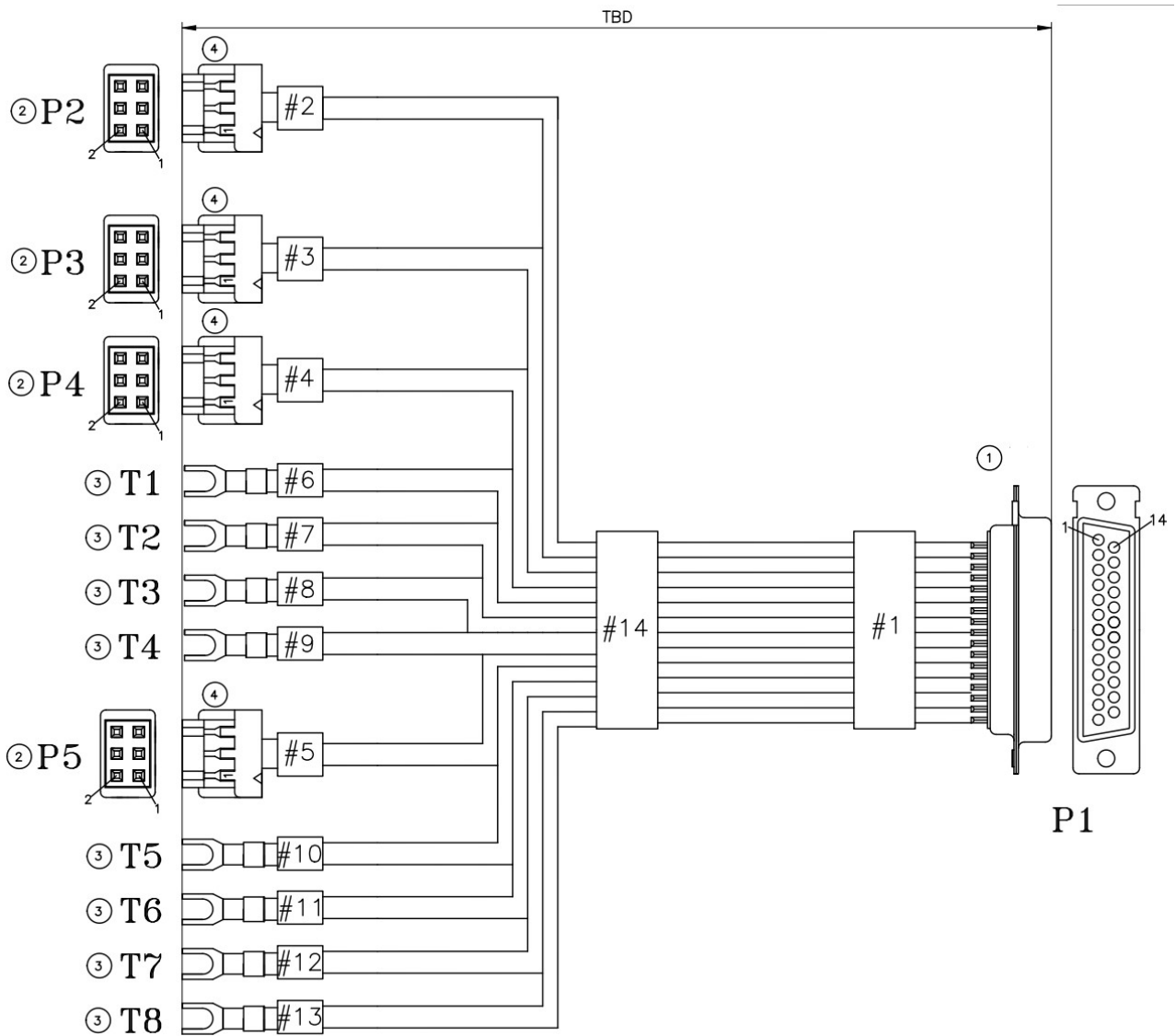


Figure 4.168 – W12 plan

4

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN / DESCRIPTION	ETIQUETA/LABEL
#1	P1 - J3-EIM_BOARD	ITEM 8
#2	P2- CN110 PS_1_MCCM	ITEM 9
#3	P3- CN110 PS_2_MCCM	ITEM 9
#4	P4- CN110 PS_3_EIM	ITEM 9
#5	P5- CN110 PS_4_EIM&DB	ITEM 9
#6	T1- PIN_4 OF PS_3(5V_RTN)	ITEM 9
#7	T2- PIN_5 OF PS_3(5V_RTN)	ITEM 9
#8	T3- PIN_6 OF PS_3(5V)	ITEM 9
#9	T4- PIN_7 OF PS_3(5V)	ITEM 9
#10	T5- PIN_4 OF PS_4(3V3_RTN)	ITEM 9
#11	T6- PIN_5 OF PS_4(3V3_RTN)	ITEM 9
#12	T7- PIN_6 OF PS_4(3V3)	ITEM 9
#13	T8- PIN_7 OF PS_4(3V3)	ITEM 9
#14	DETALLE A/DETAIL A	ITEM 8

Figure 4.169 – W12 labels

As mentioned above, the length of the cable will not be known until the EIM BOX with the sources and the EIM BOARD is assembled, and as each ramification will go to a different location, it will be much more difficult to estimate. For this purpose, in order to calculate the amount of cable that will be needed, all distances will be assumed to be equal. As the EIM BOARD connector is located in the top left corner of the board, the worst case will be the wire going to the source on the right-hand side of the EIM BOX which is closest to the front of the EIM BOX. For this purpose, to estimate this distance, the length of the bottom of the EIM BOX, plus the distance from the sidewall, will be calculated, and this distance will be assumed for all wires. Adding the two distances together gives  $483 + 466 = 949\text{mm}$  distance per wire. In this cable, as low current and low voltage power and communication signals are transmitted over such a short distance, **AWG24** will be used as the conductor, which will allow high performance using a thinner conductor.

Now, the number of wires is calculated by looking at which of the two extremes has the most pins. At the extreme end going to the sources, adding two pins per **CN100** connector plus the fork terminals gives a total of 16 pins, while at the other extreme, P1, the connector will have 25 pins. Therefore, the number of wires that should be present will be 25, and making the corresponding calculations, the following calculations are obtained:

$$\text{AWG24 WIRE} = 25 * 949\text{mm} = \mathbf{23725\text{mm}}$$

The next step is to find the labels that are going to be put on the cable. For the labels ranging from 2 to 13, the label model will be the smallest, as they will only have one or two wires of 1.13mm diameter, and, therefore, the model **TMS-SCE-2X-1K-3/32** will be used. However, for both labels 1 and 14, it will be necessary to find a label that is capable of grouping 25 cables of **AWG24**. So, making the necessary calculations as well:

$$\text{RADIUS LABELS 1 AND 14} = \text{sqrt}(25 * 0.57 * 0.57) = \mathbf{2.85}$$

With the radius obtained, the following models will be chosen for these labels:

LABEL	DIAMETER	MODEL	QUANTITY
ITEM 8	5.7	TMS-SCE-2X-1K-3/8	2
ITEM 9	1.13	TMS-SCE-2X-1K-3/32	12

#### 4.4.2.2.5 W13

This cable will be responsible for connecting the EIM BOARD with the voltmeters on the front panel, in order to check that the 3.3V and 5V power supplies are working correctly. In the cable two extremes can be distinguished, the one on the left, P1, will be the one connected to the EIM BOARD, and the one on the right, composed of two terminals, will be the one connected to the voltmeters on the front panel. The interface to which P1 is connected will be the J7 and J8 of the EIM BOARD, depending on whether it is going to measure the 3.3V or the 5V source. This interface will be a male connector with 4 contacts in a row manufactured by **HARWIN**, and searching the **HARWIN** website for a connector with the same characteristics, but female, the model **M80-1010498S** is obtained, which is available on the **RS Component** website for the following price:

**Carcasa de conector HARWIN M80-1010498S, Serie M80-10, paso: 2mm, 4 contactos, 1 fila filas, Recta, Hembra** **HARWIN**

Código RS: 680-9096 | N° ref. fabric.: M80-1010498S | Fabricante: HARWIN



213 Disponible para entrega en 24/48 horas

Precio Unidad  
**1,53 €**  
(exc. IVA) **1,85 €**  
(inc. IVA)

unidades	Por unidad
1 - 19	1,53 €
20 - 74	1,31 €
75 - 299	1,08 €
300 - 599	1,00 €
600 +	0,93 €

- 1 + unidades

Añadir

Figure 4.170 – W13 P1 connector

The other extreme of the cable will be formed by two terminals and will be connected to a voltmeter that will be located in the front of the EIM BOX. This voltmeter will be a model commonly used within the company for use in racks, and its serial number is the **DMS-20PC-3-DCM-C** from the company **MURATA POWER SOLUTIONS**, which is available from **RS Component** for the following price:

**Voltímetro digital DC Murata Power Solutions, con display LED, 3.5 dígitos, precisión ±0,01 %, dim. 33.93mm x 21.29mm** 

Código RS: 254-9131 | N° ref. fabric.: DMS-20PC-3-DCM-C | Fabricante: Murata Power Solutions



9 Disponible para entrega en 24/48 horas

1 unidades

Añadir

Disponibilidad de stock

Precio Unidad


45,37 € (exc. IVA)      54,90 € (inc. IVA)

unidades	Por unidad
1 +	45,37 €

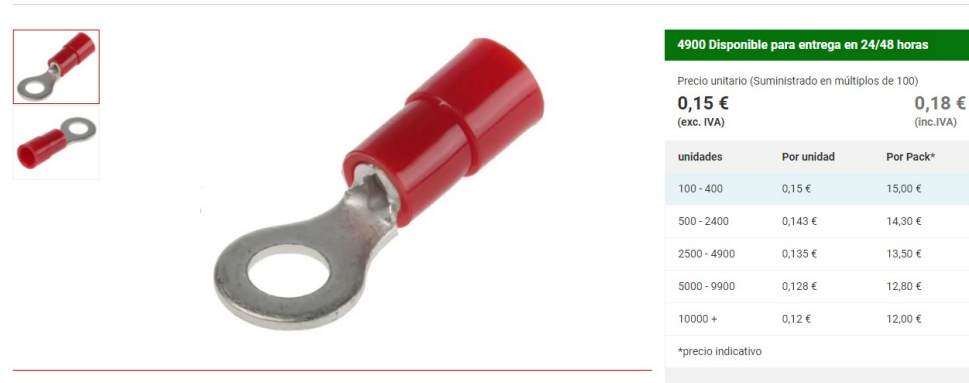
Figure 4.171 – Front panel voltmeter for W13



Analysing the datasheet of the voltmeter, it can be seen that the terminals that fit in the positive and negative poles of the voltmeter will be fixed using a M4 measuring screw, so, in order to find these terminals, it was decided to look for eyelet-shaped terminals of these dimensions. Looking at the **RS Component** website, it is possible to find the following model that will fit the characteristics required:

**Terminal redondo Phoenix Contact 3240018, C-RCI 1.5/M4, Aislado, M4, Rojo, 0.5mm<sup>2</sup> a 1.5mm<sup>2</sup>** 

Código RS: 804-6953 | N° ref. fabric.: 3240018 | Fabricante: Phoenix Contact



4900 Disponible para entrega en 24/48 horas

Precio unitario (Suministrado en múltiplos de 100)

0,15 € (exc. IVA)      0,18 € (inc. IVA)

unidades	Por unidad	Por Pack*
100 - 400	0,15 €	15,00 €
500 - 2400	0,143 €	14,30 €
2500 - 4900	0,135 €	13,50 €
5000 - 9900	0,128 €	12,80 €
10000 +	0,12 €	12,00 €

\*precio indicativo

Figure 4.172 – Eyelet-shaped terminal for W13

Now that the connectors have been chosen, the next step is to draw the plan, which will come with defined lengths, because in this case it is easier to calculate. As the interfaces J7 and J8 of the EIM BOARD will be located in the centre of the front side of the board, these will be close to the front of the EIM BOX, and, knowing that from the board to the front of the box, there is about 150mm, it is decided to establish a length for the cable of 200mm, allowing the cable not to be tense.

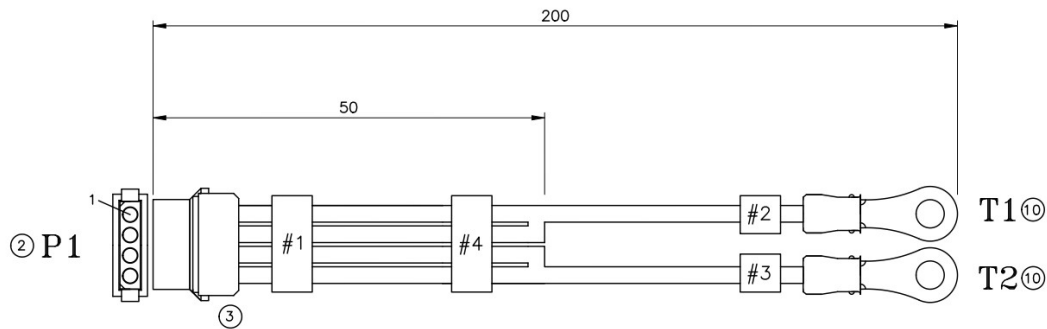


Figure 4.173 – W13 plan

4

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN / DESCRIPTION	ETIQUETA / LABEL
#1	P1 – J7/J8 EIM_BOARD	ITEM 7
#2	T1 – POSITIVE_VOLTIMETER	ITEM 7
#3	T2 – NEGATIVE_VOLTIMETER	ITEM 7
#4	Detalle "A"/Detail "A"	ITEM 7

Figure 4.174 – W13 labels

As the signals transmitted by this cable are low power, a conductor of **AWG24** will be selected. And as the drawing indicates at what height the soldering will be done, the quantity of wire will be easy to calculate:

$$\text{AWG24 CONDUCTOR} = 2 * 200\text{mm} + 2 * 50\text{mm} = \mathbf{500\text{mm}}.$$

The labels for this cable will not be difficult to calculate, since, as there are only 1 or 4 conductors for each label, the same model will be chosen for all of them:

$$\text{RADIUS LABELS W13} = \text{sqrt}(4 * 0.57 * 0.57) = \mathbf{1.14\text{mm}}$$

This measurement assumes a diameter of 2.28mm, and therefore, the label chosen will be **TMS-SCE-2X-1K-1/8**.

4.4.2.2.6 W15

The function of this cable will be to provide power to the sources inside the EIM BOX, therefore, it will have two extremes, the one connected to the electrical grid, which is where the power will enter, and which will be named P1; and the other extreme, which will be responsible for supplying the power to the sources, and will be made up of different terminals.

The connector corresponding to P1 must be able to obtain the power from the mains through the input, and distribute it through the output. As seen in the section on COTS cables, this type of panel connectors, which also function as a filter to clean the power signal, have a C13 type plug at the input, and male plugs at the output to be able to connect terminals. These sockets are fitted with a switch to cut off the current if necessary, and a fuse as a safety measure. By searching for suitable models of two-pole IEC plugs, the following model can be found, which will be selected for the cable:

**Filtro de entrada IEC, Macho, 4A, 250 V, 50 → 400Hz, C14**

SCHAFFNER

Código RS: 882-6172 | Nº ref. fabric.: FN281-4-06 | Fabricante: Schaffner



18 Disponible para entrega en 24/48 horas

Precio Unidad  
**33,09 €**  
 (exc. IVA) **40,04 €**  
(inc. IVA)

unidades	Por unidad
1 - 4	33,09 €
5 - 9	31,25 €
10 - 24	29,61 €
25 +	28,12 €

1  unidades

Figure 4.175 – W15 panel connector

As can be seen in the picture, and more clearly in the datasheet of the connector, the output pins are prepared to fit fork sockets connectors to them.

Therefore, looking on the RS Components website as well, it is possible to find the following model:



**Terminal de lengüeta RS PRO, 6.35 x 0.8mm, Aislado, Nylon 14AWG, Estaño 2.5mm<sup>2</sup>, Latón 16AWG, 21.5mm 1.5mm<sup>2</sup>**



Código RS: 267-4170 | Fabricante: RS PRO



Precio unitario (Suministrado en múltiplos de 100)

**0,199 €** (exc. IVA)      **0,241 €** (inc. IVA)

unidades	Por unidad	Por Pack*
100 - 400	0,199 €	19,90 €
500 - 2400	0,179 €	17,90 €
2500 - 4900	0,159 €	15,90 €
5000 - 9900	0,11 €	11,00 €
10000 +	0,103 €	10,30 €

\*precio indicativo

− 100 + unidades

Añadir

**Figure 4.176** – Fork sockets connectors

4

The IEC connector will have three output pins, phase, earth and neutral, and for that reason, it will be necessary to buy three of these terminals.

At the other extreme, where it goes to each of the sources, it is necessary to put fork terminals like the ones selected for the W12 cable. As can be seen in the datasheet of the power supplies, each of the power supplies will have three power pins, which will be 1, 2, and 3, corresponding to AC/L, AC/N, and FG respectively. As there will be 3 of these power interfaces per supply and there will be 4 power supplies to work with, 12 connectors will be needed as the following one:

**Terminal de horquilla Phoenix Contact, Serie C-FCI 2.5/M3.5, Aislado, M3.5, Azul No Recubierto, 1.5mm<sup>2</sup> a 2.5mm<sup>2</sup>**



Código RS: 804-6962 | Nº ref. fabric.: 3240038 | Fabricante: Phoenix Contact



993 Disponible para entrega en 24/48 horas

Precio Unidad  
**0,27 €** (exc. IVA)      **0,33 €** (inc. IVA)

unidades	Por unidad
1 - 4	0,27 €
5 - 24	0,25 €
25 - 49	0,24 €
50 - 74	0,23 €
75 +	0,21 €

− 1 + unidades

**Figure 4.177** – Fork terminal



Once all the terminals that are going to form the cable are in place, the design of the cable, whose length, as with most of the cables within the EIM BOX, is not known yet, will be defined as TBD

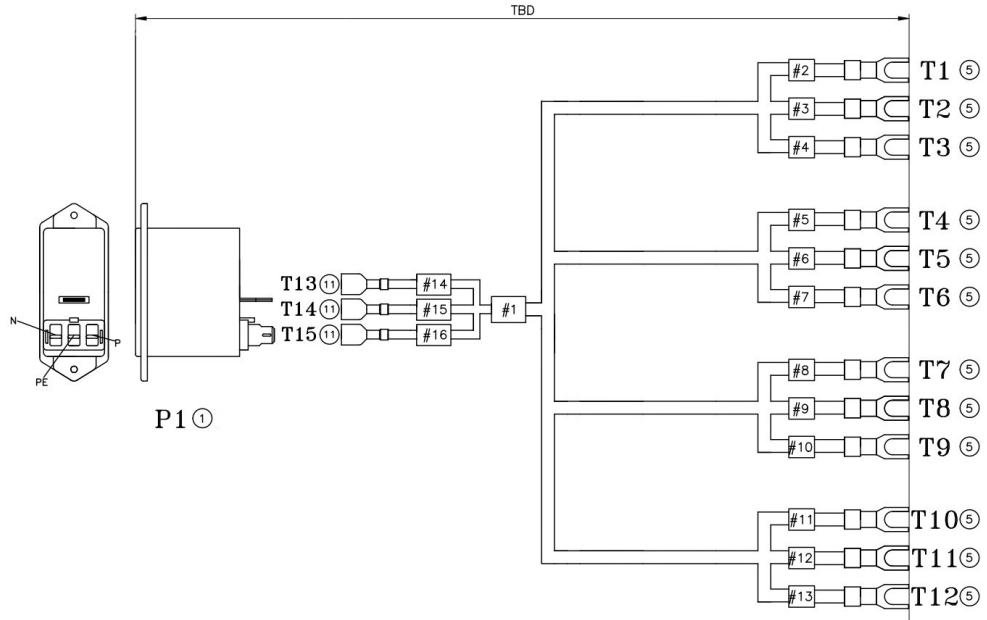


Figure 4.178 – W15 plan

TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE		
#	DESCRIPCIÓN / DESCRIPTION	ETIQUETA/LABEL
#1	DETALLE A/DETAIL A	ITEM 8
#2	T1 – PIN_1 OF PS_1 (AC/L)	ITEM 8
#3	T2 – PIN_2 OF PS_1 (AC/N)	ITEM 8
#4	T3 – PIN_3 OF PS_1 (GND)	ITEM 8
#5	T4 – PIN_1 OF PS_2 (AC/L)	ITEM 8
#6	T5 – PIN_2 OF PS_2 (AC/N)	ITEM 8
#7	T6 – PIN_3 OF PS_2 (GND)	ITEM 8
#8	T7 – PIN_1 OF PS_3 (AC/L)	ITEM 8
#9	T8 – PIN_2 OF PS_3 (AC/N)	ITEM 8
#10	T9 – PIN_3 OF PS_3 (GND)	ITEM 8
#11	T10 – PIN_1 OF PS_4 (AC/L)	ITEM 8
#12	T11 – PIN_2 OF PS_4 (AC/N)	ITEM 8
#13	T12 – PIN_3 OF PS_4 (GND)	ITEM 8
#14	T13 – J3–EIM_BOX(N)	ITEM 8
#13	T14 – J3–EIM_BOX(PE)	ITEM 8
#14	T15 – J3–EIM_BOX(P)	ITEM 8

Figure 4.179 – W15 labels



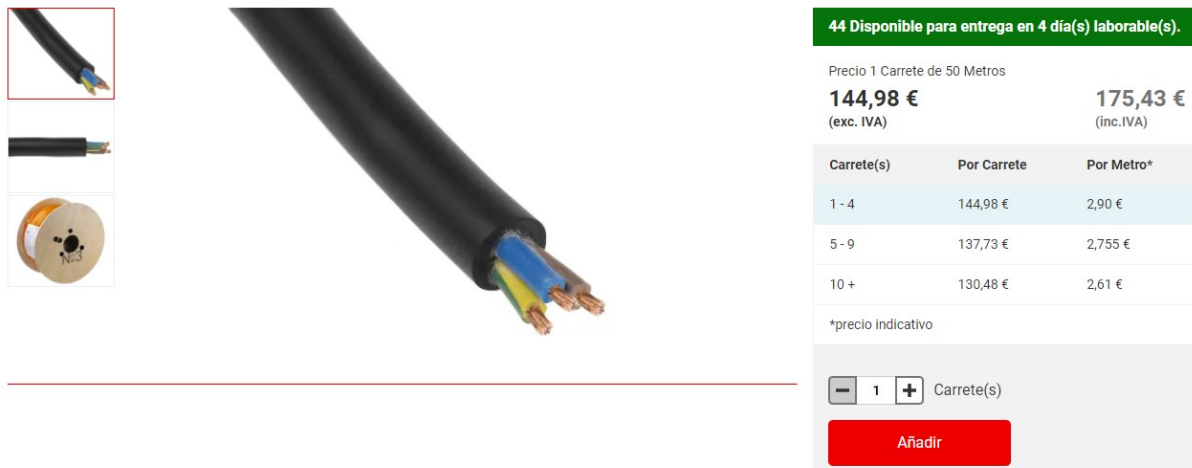
For this cable, a special wire will be used, since, when carrying power from the electrical grid, it will be possible to use prefabricated cables such as those for domestic use. These cables have three wires, each with a different coating, which indicates which type of cable it is. The colour code of these cables is as follows:

- **BROWN:** This colour indicates that the wire is the one containing the phase.
- **BLUE:** This colour indicates that the wire is the one that contains the neutral.
- **GREEN AND YELLOW:** This represents the earth or ground of the cable.

These cables, usually PVC coated, can be purchased anywhere, and it is available at **RS Component** for the following price:

### Cable de Alimentación Lapp 1600118, 3 núcleos, funda de Caucho, Negro, 10.9 → <sup>®</sup>LAPP 14mm DE, 450/750 V, H07RN-F,

Código RS: 817-9006 | Nº ref. fabric.: 1600118 | Fabricante: Lapp



**44 Disponible para entrega en 4 día(s) laborable(s).**

Precio 1 Carrete de 50 Metros  
**144,98 €** (exc. IVA)      **175,43 €** (inc.IVA)

Carrete(s)	Por Carrete	Por Metro*
1 - 4	144,98 €	2,90 €
5 - 9	137,73 €	2,755 €
10 +	130,48 €	2,61 €

\*precio indicativo

− 1 + Carrete(s)

**Añadir**

**Figure 4.180** – Cable price for W15

As this cable comes in reels of 50 metres and its use is going to be limited to this cable, it will not be necessary to estimate the number of metres of cable to be ordered, as the whole reel will be ordered and later in the manufacturing process it will be seen how much is necessary.

In the case of labels, as the material covering the cable is PVC, it will be decided not to use heat-shrinkable labels, to avoid possible damage to the cable, and, therefore, an adhesive label will be used, like those used on other cables, which will indicate where each of the branches of the cable goes. At the extremes of the cable, labels will not be necessary, even if they are marked on the plan, as the colour of the cable clearly shows the function of each one of them.

#### 4.4.2.2.7 W34

This cable will be responsible for transporting the power that will be responsible for supplying the MCCM DUMMYS, from the 12V sources to the front panel of the EIM BOX. On the way between these two extremes of the cable, fuses and voltmeters will be used to prevent possible failures.

The extreme of the cable that goes to the front of the EIM BOX, will be connected to the J1.c. interface of the W01, whose connector has 44 male pins. The connector that will fit here will be the opposite, 44-pin female connector, which is the same as the one used for P2.c. on W01.

#### Conector D-sub HARTING, paso 2.29mm, Recta D-sub con contactos mixtos, Montaje de Cable, Hembra, Terminación Soldador



Código RS: 666-2887 | N° ref. fabric.: 09563004704 | Fabricante: HARTING



Precio Unidad

**5,67 €**  
(exc. IVA)

**6,86 €**  
(inc. IVA)

unidades	Por unidad
1 - 9	5,67 €
10 - 19	5,09 €
20 +	4,55 €

- 1 + unidades

Añadir

Figure 4.181 – J1.c. and J2.c. connector price

At the other extreme, as it is connected to the output terminals of the internal sources, it will be purchased fork terminals that have already been used on the other cables.

**Terminal de horquilla Phoenix Contact, Serie C-FCI 2.5/M3.5, Aislado, M3.5, Azul No Recubierto, 1.5mm<sup>2</sup> a 2.5mm<sup>2</sup>** 

Código RS: 804-6962 | Nº ref. fabric.: 3240038 | Fabricante: Phoenix Contact



993 Disponible para entrega en 24/48 horas

Precio Unidad  
**0,27 €**  
 (exc. IVA) **0,33 €**  
(inc.IVA)


unidades	Por unidad
1 - 4	0,27 €
5 - 24	0,25 €
25 - 49	0,24 €
50 - 74	0,23 €
75 +	0,21 €

− 1 + unidades

Figure 4.182 – Fork terminals price

4

Now, the two extremes of the cable are in place, but, as mentioned before, this cable will pass through fuses and voltmeters as a method of prevention. These elements will be located on the front panel of the EIM BOX, and will be models used in previous projects of the company. The voltmeter model is the **DMR20-10-DCM-R-C** from the company **MURATA POWER SOLUTIONS**, and which can measure voltages from 6V to 75V, and the fuse holder model is the **FX0455/S** from the company **BULGIN**, both of them are available at **RS Components** website, with the following prices:

**Voltímetro digital DC Murata Power Solutions, con display LED, 4 dígitos, precisión ±0.06 V, ±0.4 V, dim. 30.73mm** 

Código RS: 810-3321 | Nº ref. fabric.: DMR20-10-DCM-R-C | Fabricante: Murata Power Solutions



24 Disponible para entrega en 24/48 horas

Precio Unidad  
**41,87 €**  
 (exc. IVA) **50,66 €**  
(inc.IVA)

unidades	Por unidad
1 +	41,87 €

− 1 + unidades

Añadir

Disponibilidad de stock

Figure 4.183 – Voltmeter panel connector

**Portafusibles para montaje en panel Bulgin FX0455/S, 10A, Ranurado, 5 x 20mm, PC2, Serie FX 250V**



Código RS: 359-5719 | N° ref. fabric.: FX0455/S | Fabricante: Bulgin



**2310 Disponible para entrega en 24/48 horas**

Precio unitario (Suministrado en múltiplos de 5)

**3,228 €** (exc. IVA)      **3,906 €** (inc. IVA)

unidades	Por unidad	Por Pack*
5 - 45	3,228 €	16,14 €
50 - 245	2,906 €	14,53 €
250 - 495	2,646 €	13,23 €
500 - 1245	2,518 €	12,59 €
1250 +	2,422 €	12,11 €

\*precio indicativo

**Figure 4.184** – Fuse panel connector

On the voltmeter, the connection interfaces are located on the rear side, and the connection is made using screws which are responsible for fastening the inserted cables. Therefore, in order to connect the W34, only the stripped wire must be used.

The fuse holder, as can be seen in the picture, has two perforated metal sheets, which will function as connection interfaces, and through them, the corresponding wire will be introduced to keep the cable connected.

The connections from the cable to these terminals will be made in a different way, since, as it is known, voltmeters have to be connected in parallel to be able to measure the difference of potential between two points; and fuses, as they work as current cutters, will have to be placed in series with the cable.

As this cable will be responsible for feeding all the MCCM DUMMYS, and there is only one source per rack, this cable will be designed for the two lines instead of making one per line as it happens with other cables.

Once all the elements have been chosen, the plan that will shape this cable can be drawn:



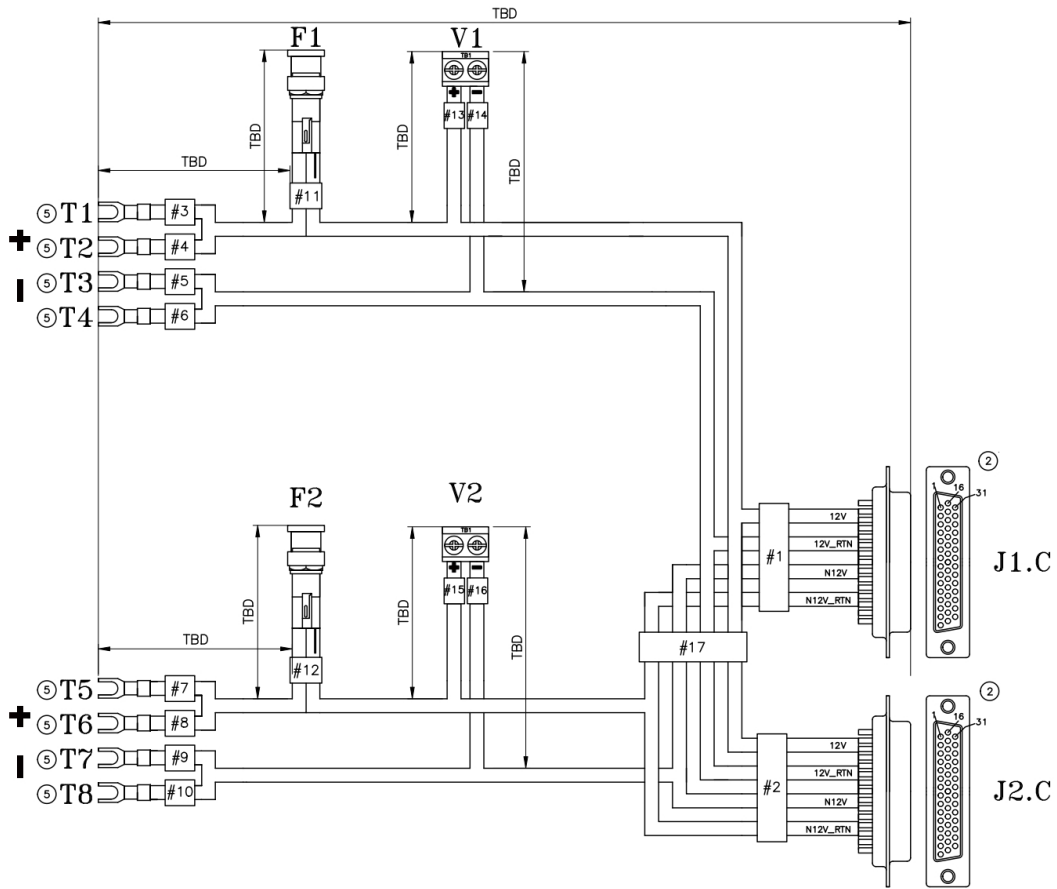


Figure 4.185 – W34 plan

#	TABLA IDENTIFICACIÓN ETIQUETAS / LABELS TABLE DESCRIPCIÓN/ DESCRIPTION	ETIQUETA/LABEL
#1	J1.C. – P1.C. EIM_BOX	ITEM 9
#2	J2.C. – P2.C. EIM_BOX	ITEM 9
#3	T1 – PIN_6 OF PS_1(12V)	ITEM 10
#4	T2 – PIN_7 OF PS_1(12V)	ITEM 10
#5	T3 – PIN_4 OF PS_1(12V_RTN)	ITEM 10
#6	T4 – PIN_5 OF PS_1(12V_RTN)	ITEM 10
#7	T5 – PIN_6 OF PS_2(12V)	ITEM 10
#8	T6 – PIN_7 OF PS_2(12V)	ITEM 10
#9	T7 – PIN_4 OF PS_2(12V_RTN)	ITEM 10
#10	T8 – PIN_5 OF PS_2(12V_RTN)	ITEM 10
#11	F1 – TO FUSEHOLDER 1	ITEM 10
#12	F2 – TO FUSEHOLDER 2	ITEM 10
#13	V+ FROM VOLTIMETER 1	ITEM 10
#14	V- FROM VOLTIMETER 1	ITEM 10
#15	V+ FROM VOLTIMETER 2	ITEM 10
#16	V- FROM VOLTIMETER 2	ITEM 10
#17	DETALLE A/DETAIL A	ITEM 9

Figure 4.186 – W34 labels

As can be seen on the plan, the distances will be undefined for this cable, and therefore, as with most internal cables, the quantity of wire will be undefined. In this particular case, the distances will be much more difficult to calculate due to the number of connections along the cable and the position of the sources. However, as the 12V sources will be located on the right side of the EIM BOX, the cable distance will be calculated by assuming that the connectors on the front of the EIM BOX are located at the furthest point from the sources. This would be approximately the same distance as the width and length of the EIM BOX, which is 949mm as seen on the W12.

As in all terminals, except for J1.c. and J2.c., a single wire will have to be connected, the necessary soldering will have to be done in order to go from 11 pins, 44 pins divide between the 4 different sections of the voltages, to a single wire. The path made with a single conductor, will be made with a thickness of **AWG16**, while, the path that comes out of the front conductors, will be made with **AWG22**. To avoid future complications, it will be assumed that the soldering to change from 11 cables to one will be made at 150mm, so that the margin of error is greater for the quantity of wire of **AWG16** and less for that of **AWG22**, which is better for the use of a smaller number of wires in the first one. Therefore, performing the corresponding calculations:

**AWG 16 WIRE:**  $799\text{mm} * 8 = 6392\text{mm}$  **AWG 22 WIRE:**  $150\text{mm} * 88 = 13200\text{mm}$

For the labels that are responsible for identifying the cable, the following models will be chosen depending on which ones are used. For labels ranging from 3 to 16, the model corresponding to item 10 will be used, as it will group a single **AWG16** wire. However, for labels 1, 2, and 17, a different model, item 10, will be used, as each one is responsible for grouping forty-four **AWG22** wires:

**LABELS 1, 2, 17 RADIUS:**  $\text{sqrt}(44 * 0.64 * 0.64) = 4.24$

LABEL	DIAMETER	MODEL	QUANTITY
ITEM 8	8.48	TMS-SCE-2X-1K-1/2	3
ITEM 9	2.1	TMS-SCE-2X-1K-1/8	14

This completes the design of the cables, both external and internal, and moves on to the last part, which is the design of the front panel of the EIM BOX.

### 4.5 EIM BOX front design

Now that all the elements that will compose this fundamental part of the rack are found, it will be necessary to find the way to distribute them along the front of the EIM BOX. The measurements of each of the components of the rack can be obtained from their datasheet, and, after that, it is only necessary to think about the distribution to be given.

To make the distribution of the EIM BOX connectors more organized, all the components corresponding to the W01, which will be the only EGSE cable connecting the rack with the UUTs, will be placed on the left side of the front panel.

This will leave the right-hand space for the **IEC** connector of the W15 cable, keeping on that away the W15 apart from the cables that transmit the communication signals, the W10s. Placing it on the upper right-hand side will also help to distribute the W15 along the upper sides of the EIM BOX.

On the right side, but in the lower part, the connectors containing the cables that are connected to the Laptop and which will transmit EGSE control signals will be located, such as the **ETHERNET** and **USB** panel connector. and the vacuum chamber connector in case it is necessary to use the vacuum chamber.

In the central part, therefore, space will be left to place the voltmeters used on the rack to check that the sources are working well, and at the lower part, there will be placed the fuses and the vacuum chamber connector.

The aforementioned distribution would then be as follows:

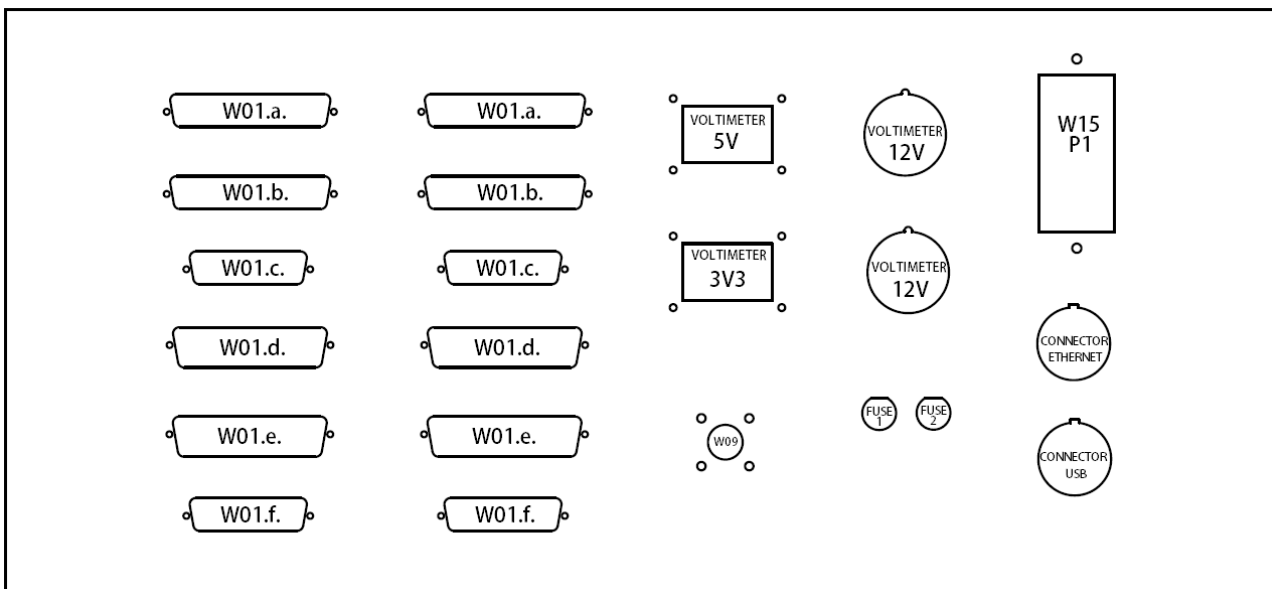


Figure 4.187 – Front panel design



In the image, it is possible to see the final distribution as mentioned above, and with this, the EGSE design chapter is finished, although it should be clarified that there may be changes as the implementation process progresses, and these will be explained as they happen.

4

# EGSE Implementation

Once the EGSE design process has been completed, the next step will be the reception of the materials and the implementation of all of these to form the test equipment together.

This last part corresponds to the work done by the company's technicians, who do all this kind of work in clean rooms with the necessary tools, and are used to working on rack assemblies. Because of this, this chapter will be more focused on showing the process by which the rack has been built, rather than explaining how it has been assembled.

Because many of the cables in the rack will depend on some of the rack modules, the first part to be designed will be the EGSE MAINFRAME. Once all the components have been selected and are sorted in [SAP](#) lists, the next step is to launch them, which means that the purchasing department of the company is responsible for making the necessary arrangements for the shipment of these components to the company's headquarters. These shipments will not be the same for all components, as depending on the distributor and the company that is responsible for manufacturing them, it will take more or less time.

As soon as the design of the EGSE MAINFRAME is finished, and while all the components of the EGSE MAINFRAME are arriving, the next step is the design of the cables, which will consist of the drawing of the plans, the recommended assembly instructions, and the design of the PINOUT between the extremes of the cable. As with the EGSE MAINFRAME, as the cables are designed, lists of materials are drawn up in [SAP](#) with the necessary components for each one, and once they have all been designed, the shopping lists are launched, and the materials are awaited.

Fully defined cables, such as EXT CABLES, can begin to be manufactured as soon as the material is received, as the dimensions of these are indicated in the drawings, however, for those that are not defined, such as many of the INT CABLES, it will be necessary to wait until the EIM BOX is assembled, and measure the necessary lengths inside it.

As the different rack components are received, the software team will be responsible for

configuring the computer-controllable modules, and will carry out various tests before the installation, to check that they work correctly.

Once all the rack components are ready, the company's technicians will assemble the different parts that make up the rack. At the same time, from the cable section of the company, the technicians will be responsible for assembling the fully defined cables, following the steps marked on the drawings.

The layout inside the rack will start with the lower part occupied by a drawer included in the rack at the front, and the rack-mounting strip at the rear. Above this level will be the 3U occupied by the rack power supplies, and above these, the EIM BOX. At the top of the rack, and leaving 1U of space with respect to the EIM BOX, the PPU will be placed at the front and the DIN RAIL with all its components at the rear.

All the rack and cable assembly will be done under the supervision of the author, so that, in this way, it is possible to have under control that all the modules and components of the rack are being assembled and installed in the correct position.

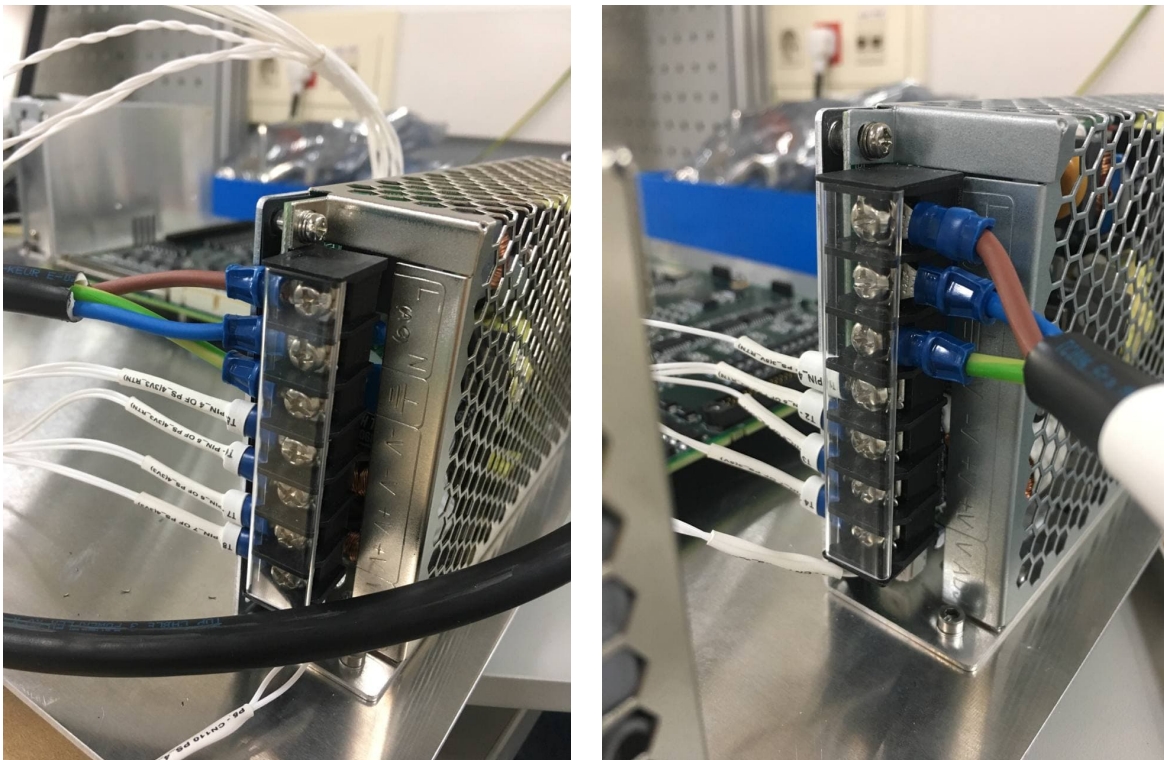
While the strip and the rack power supplies are installed inside the rack, the EIM BOX will be assembled in order to analyse the lengths and spaces available inside the rack. For this purpose, the fixed modules, which are the EIM BOARD and the power supplies for the EGSE boards, will be installed in the EIM BOX. Once they are in position, the appropriate distance from each of the interfaces of the EIM BOARD to the necessary connectors will be measured by means of a string.

During these measurements, the most problematic cables will be W12 and W15, which are the cables that go from the EIM BOARD to the power supplies inside the EIM BOX, and from these power supplies to the front panel of the EIM BOX. Making the corresponding measurements, and applying them to the indicated cables, they will be tested inside the EIM BOX, in order to check their correct installation.



**Figure 5.1** – *EIM BOX plant*

In the image above, it is possible to see the final result of the installation of the EIM BOARD and the power supplies of the EGSE boards, and how the W12 and W15 cables are checked. It can be seen that the correct measurements have been taken for both cables, as, once installed, they are neither too tight or too loose.

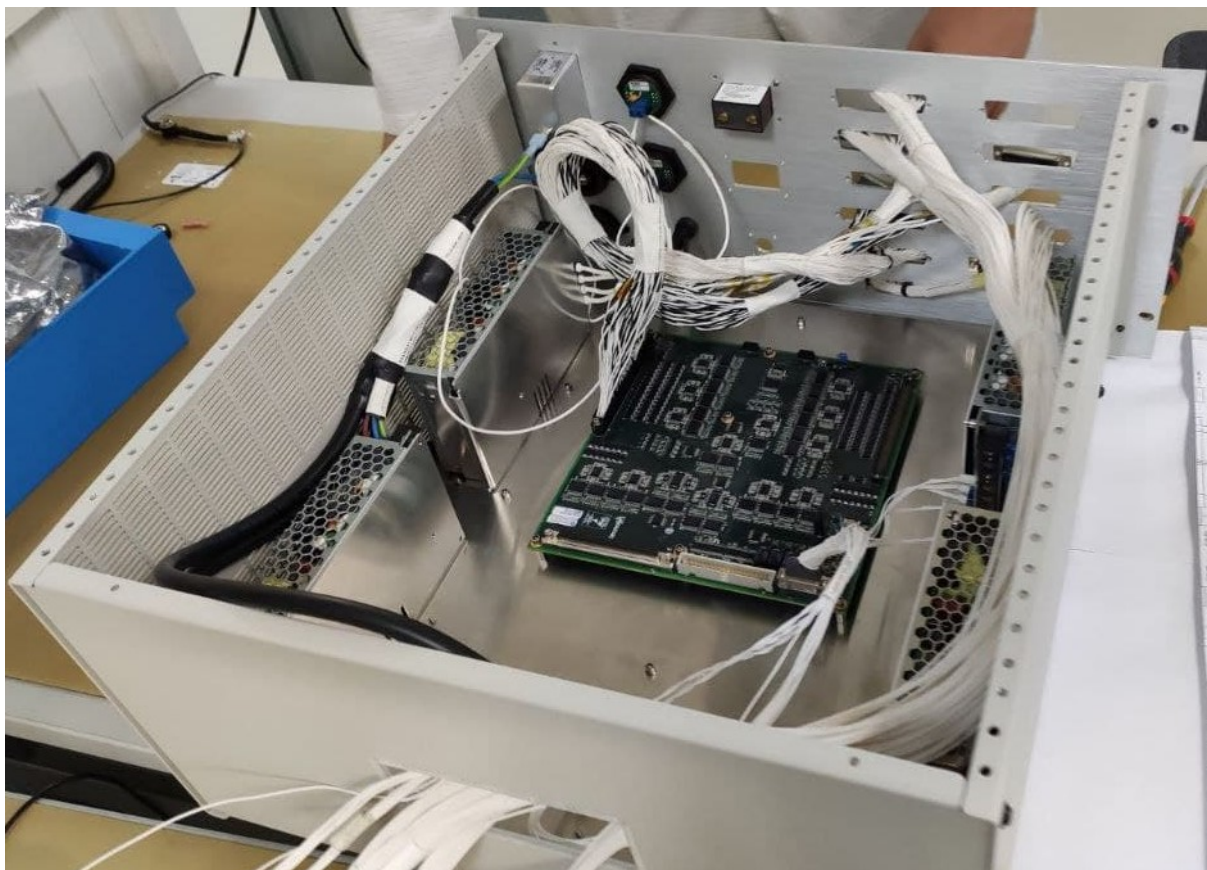


**Figure 5.2** – *EGSE boards power supplies connection detail*

## 5

In the images above, you can see a detail of the connection of both W12 and W15 to the internal sources of the EIM BOX, specifically to the 3.3V and 5V sources. The W12 will be connected by a white conductor to the 4 lower terminals of the power supply, and it will also plug in the CN100 connectors of the power supplies. The W15 cable, however, will be the one to be connected through the first three terminals of the sources, and as indicated in the section of this cable, it will be connected through a black PVC cable whose terminals do not need a label, as their colour clearly indicates the position of each one.

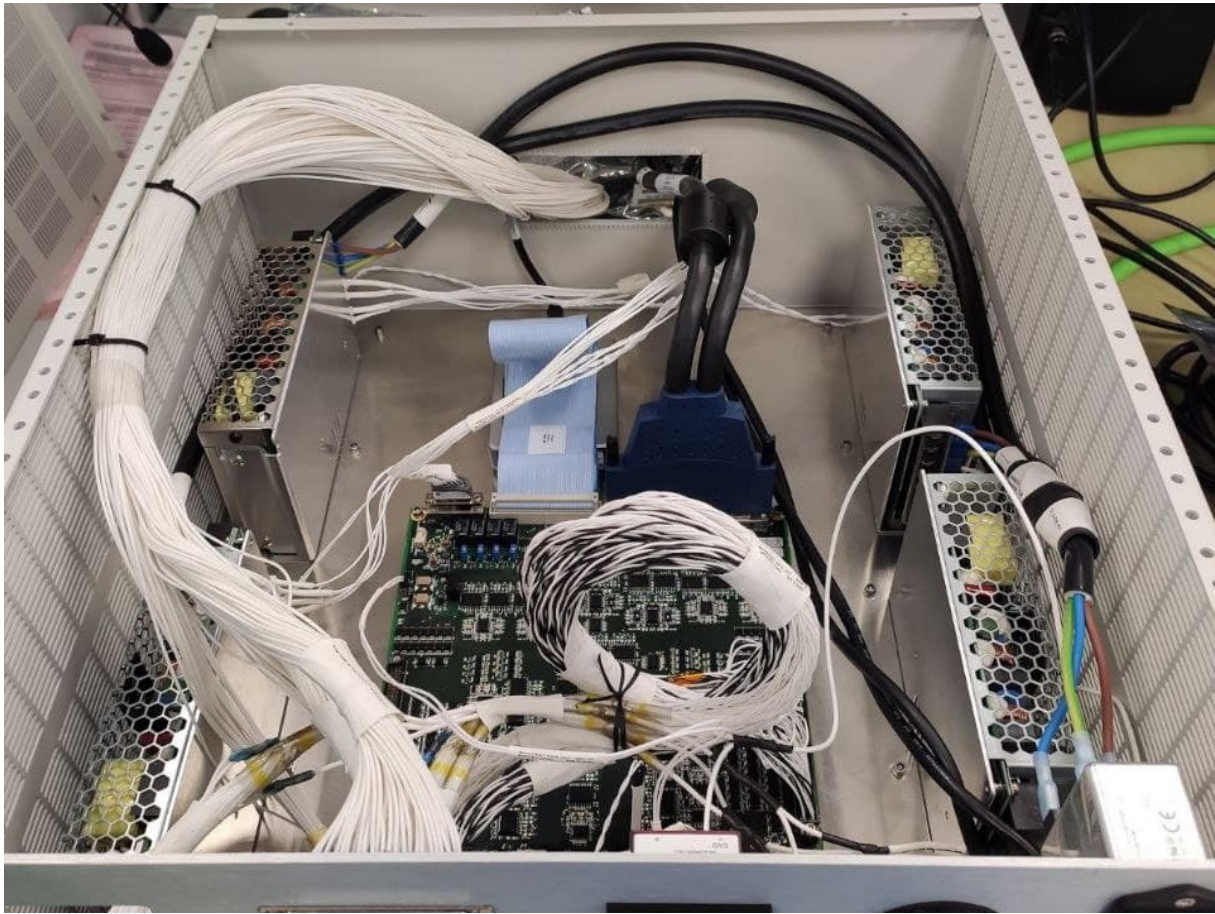
This same process is now carried out for cables whose measurement is not defined, but whose length has been estimated with greater precision, such as W10, W11, or W34.



**Figure 5.3** – *W10, W11 and W34 checking*

In the image can be seen the process of checking the cables mentioned above, where the front panel of the EIM BOX has already been mechanised, and some of the components that integrate it have started to be installed. It can also be seen that a rectangular hole has been drilled in the back of the EIM BOX through which the cables connected to other modules in the rack will pass.

Now the rest of the INT CABLES of the rack are installed and placed inside the EIM BOX.



**Figure 5.4** – *EIM BOX with all the cables*

5

It is possible to see how the USB-SPI has been installed inside the EIM BOX without any problem, as it had been calculated during the design phase. It is also possible to observe the fastenings given to some of the cables, such as the W11, which goes along the left side of the EIM BOX and is attached to this wall with cable ties. Once the front panel components have been installed, and the cables inside the EIM BOX have been installed, the box is closed and checked for correct operation.



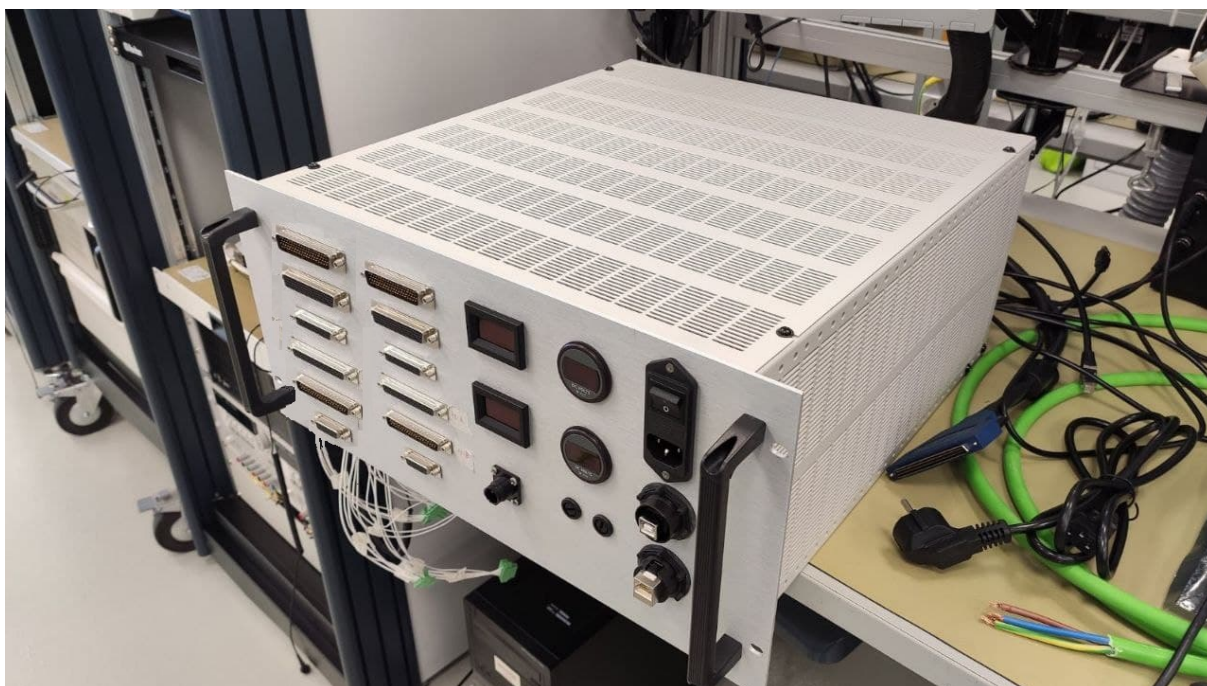


Figure 5.5 – EIM BOX close



Figure 5.6 – EIM BOX working

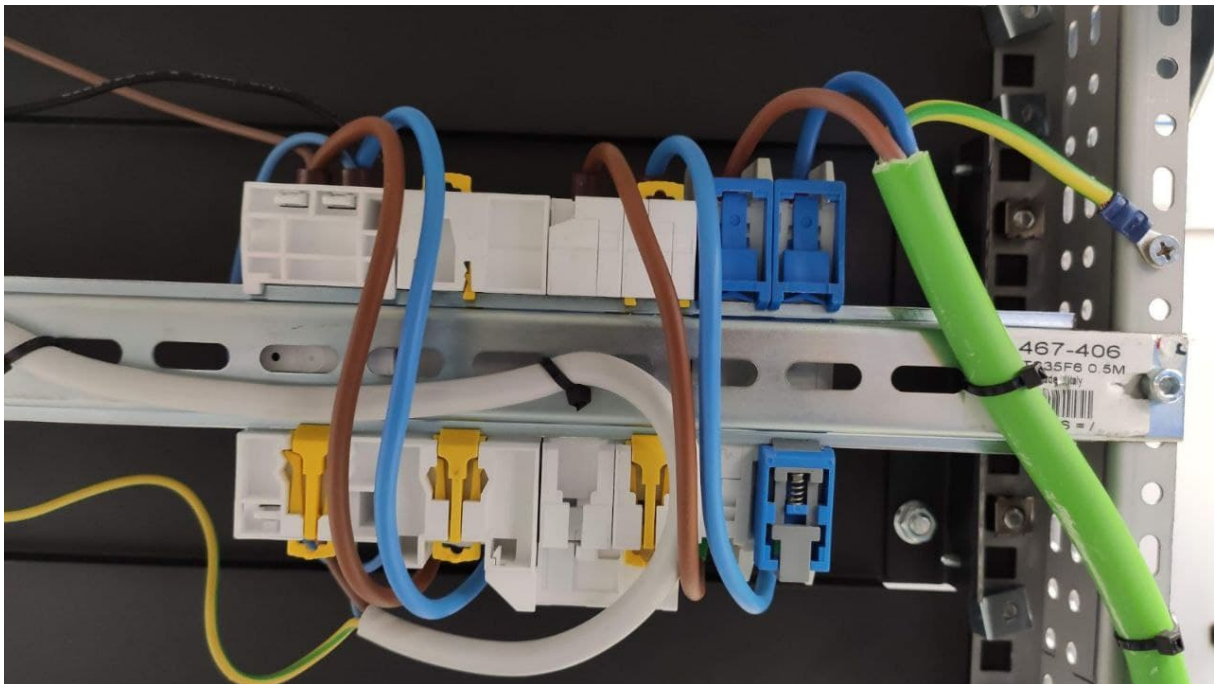
As can be seen, the internal supplies of the EIM BOX are working properly, and it can be seen how they are powered through the connection between the W15 and W21 on the IEC front panel. Below this are the two computer connection ports, one USB and one ETHERNET.

While the EIM BOX is being assembled, the PPU is also installed inside the rack, which once finished will look like this:



**Figure 5.7** – PPU frontal detail

An external metal plate has been added to this section of the rack, to make it look more elegant, and to identify it by means of adhesive labels. All the components of the PPU are clearly visible, as well as the emergency button, which, although it is located away for better visibility, is connected to the relay. These connections are not visible thanks to the metal plate inserted, but the connections, seen from the rear, would look as follows.



**Figure 5.8** – PPU rear view detail

In the same way, the DIN rail components are installed, which will be located at the rear of the rack.



**Figure 5.9** – PPU rear view detail

Here it can be seen how the USB HUB, the ETHERNET SWITCH, and the 24V power supply are installed on the DIN rail. The other module that should be installed on this rail is the USB-DIOs, but it was decided to place it on the EIM BOX, as, due to its size and weight, it could be unstable on the DIN rail.

Once the EIM BOX is finished, it is installed inside the rack, between the rack sources and the DIN rails, leaving the rack as follows.



Figure 5.10 – Rack front view



**Figure 5.11** – *Rack back view*

Once all the rack modules have been installed, the rack is closed and some basic tests are carried out on the boards to check the correct operation of the rack and the EGSE cables.

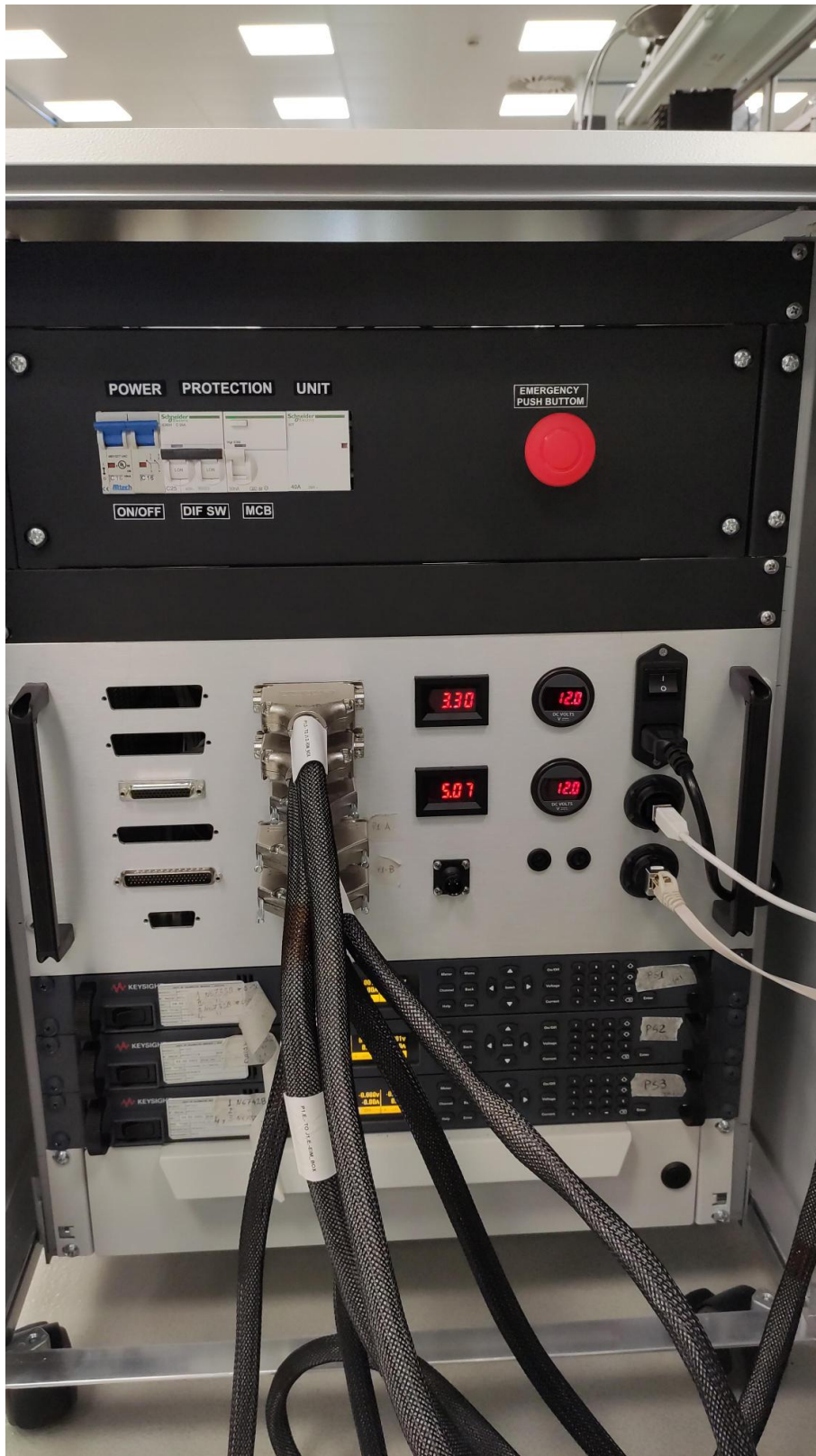
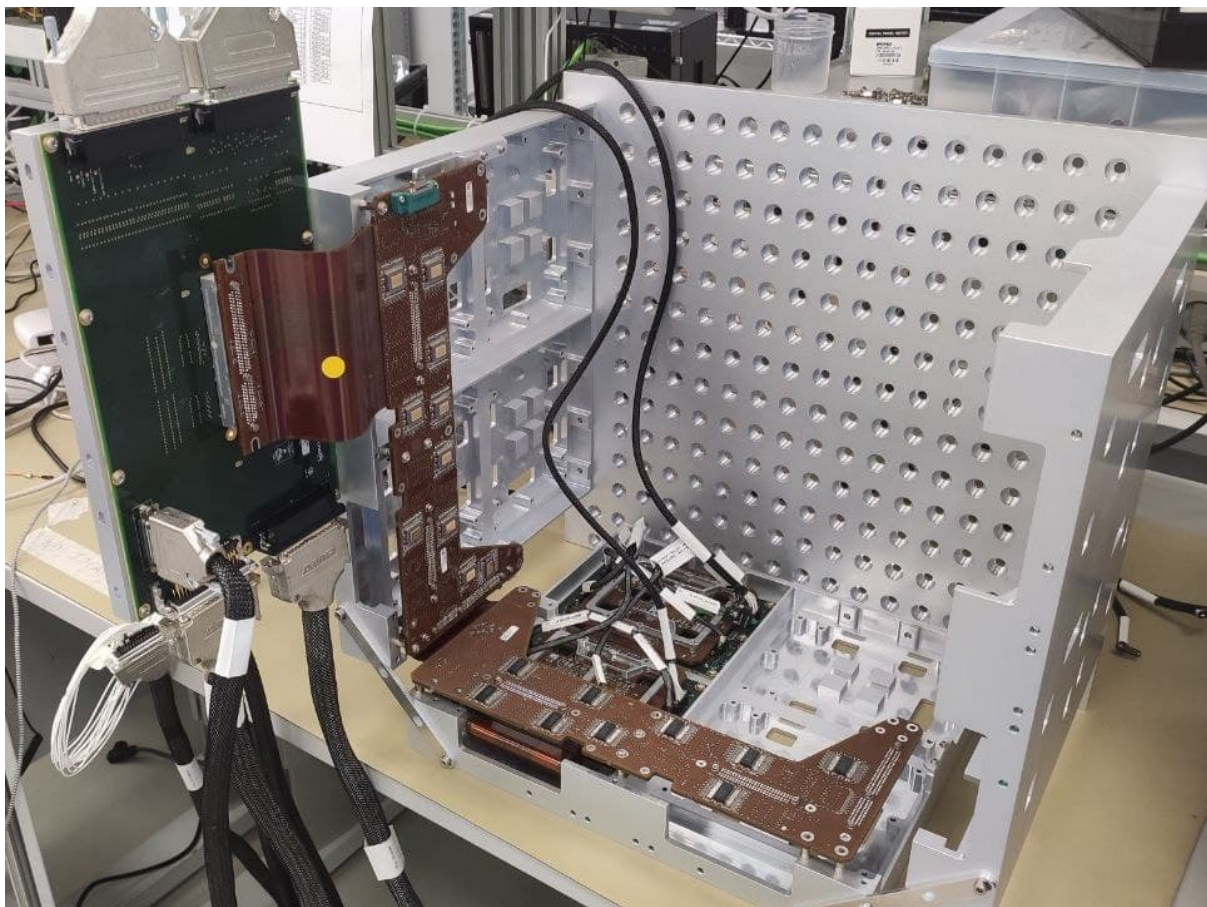


Figure 5.12 – Rack working



**Figure 5.13** – *EGSE cables test with boards*

With these basic continuity and short-circuit tests between the cables, the correct operation of the EGSE is verified, and therefore its correct design.





# Chapter 6

## Budget

In this section the total price will be divided into the different sections dealt with throughout the project, and then all of these will be added together.

Starting with the MAINFRAME EGSE, adding up all the costs of the modules that make it up, the following price is obtained.

	SERIAL NUMBER	PRICE PER UNIT	QUANTITY	TOTAL PRICE
<b>EGSE_MAINFRAME</b>				
EIM_BOX	665-7649	80,03	1	80,03
<b>EGSE_BOARDS_POWER_SUPPLIES</b>				
12V POWER SUPPLY	HRPG-150-12	53,78	2	107,56
5V POWER SUPPLY	HRPG-150-5	53,78	1	53,78
3V3 POWER SUPPLY	HRPG-150-3.3	53,78	1	53,78
IVA				33,88
<b>UUT's POWER SUPPLIES</b>				
4 SLOTS MAINFRAME	N6700C	2553	3	7659
POWER MODULE MODEL 1	N6742B	925,3	2	1850,6
POWER MODULE MODEL 1	N6732B	531	8	4248
POWER MODULE MODEL 1	N6733B	531	2	1062
RACK MOUNTING KIT FOR POWER SUPPLIES	34190A	62,83	3	188,49
IVA				3095,94
<b>DIN-RAIL</b>				
USB_SPI	USB-8452	783	1	783
USB_DIOs	USB-6509	566	1	566
SWITCH_ETHERNET	EDS-205A	88,17	1	88,17
HUB_USB	ST7300USBME	105,74	1	105,74
POWER SUPPLY	ABL8RPS24030	193	1	193
DIN-RAIL	6ESS710-8MA11	55	2	110
LAPTOP	Satellite Pro C50-E	689	1	689
<b>POWER PROTECCION UNIT (PPU)</b>				
CIRCUIT BREAKER	A9F92203	348,85	1	348,85
DIFFERENTIAL SWITCH	A9Q21225	370,61	1	370,61
EMERGENCY STOP BUTTON	XB4BT842	51,51	1	51,51
RELAY	A9C22712	75,52	1	75,52
GENERAL SWITCH	2CU3L	42,56	1	42,56
POWER STRIP	DK 7240220	70,99	1	70,99
RACK	SMA20024	747,84	1	747,84
<b>TOTAL</b>				<b>22675,85</b>

Figure 6.1 – EGSE mainframe budget

The cost of all the COTS cables is now analysed, whose total price is:

<b>CABLES_EXT</b>	<b>PRICE PER UNIT</b>	<b>QUANTITY</b>	<b>TOTAL</b>
W14	231	1	231
W16	18,9	1	18,9
W17	2,19	1	2,19
W18	INCLUDE		
W19	4,25	1	4,25
W20	4,02	1	4,02
W21	17,22	1	17,22
W22	9,08	1	9,08
W23	INCLUDE		
W24	INCLUDE		
W25	NONE IN THIS SECTION		
W26/W35/W36	23,41	6	140,46
W27	INCLUDE		
W28	INCLUDE		
<b>TOTAL</b>			<b>427,12</b>

**Figure 6.2** – *COTS cables budget*

The following one is the total price of the different components from the TBT cables, without count with the wires, labels, and polyester braided sleeves:

	CABLE	CONNECTOR	OTHERS COMPONENTS	PRICE	QUANTITY	CABLE TOTAL	UNITS OF CABLE	TOTAL PRICE		
<b>CABLES_EXT</b>	<b>W01</b>	62 SKT SUB-D		7,722	2	15,444				
		62 PIN SUB-D		6,939	2	13,878				
		44 SKT SUB-D		6,86	1	6,86				
		78 SKT SUB-D		10,356	2	20,712				
		78 PIN SUB-D		9,457	2	18,914				
		26 PIN SUB-D		3,692	1	3,692				
		44 PIN SUB-D		4,813	1	4,813				
		26 SKT SUB-D		3,078	1	3,078				
				BACKSHELL 37W	9,86	4	39,44			
				BACKSHELL 25W	7,54	2	15,08			
				BACKSHELL 15W	4,67	2	9,34			
				BACKSHELL 50W	8,59	4	34,36			
				COOPER SLEEVE	1,42	6	8,52			
						<b>TOTAL</b>		<b>194,131</b>	<b>2</b>	<b>388,262</b>
		<b>W03</b>	15 SKT Micro-D			81,65	1	81,65		
3 SKT SOLDER				0,61	7	4,27				
2 PIN SOLDER				0,137	2	0,274				
	BREADBOARD			4,78	1	4,78				
					<b>TOTAL</b>		<b>90,974</b>	<b>2</b>	<b>181,948</b>	
<b>W05/W06</b>	15 SKT Micro-D			81,65	1	81,65				
	222S06M16			28,95	2	57,9				
					<b>TOTAL</b>		<b>139,55</b>	<b>24</b>	<b>3349,2</b>	
<b>W08</b>	44 PIN SUB-D			4,813	1	4,813				
	222S10M16			26,84	12	322,08				
		BACKSHELL 25W		7,54	1	7,54				
					<b>TOTAL</b>		<b>334,433</b>	<b>2</b>	<b>668,866</b>	
<b>W50</b>	40 PIN CABLE			17,97	1	17,97				
	JTAG CABLE			11,69	1	11,69				
					<b>TOTAL</b>		<b>29,66</b>	<b>1</b>	<b>29,66</b>	

**Figure 6.3** – *CABLES EXT* components price

<b>CABLES_INT</b>	<b>W09</b>	101C02L	3,54	1	3,54		
		2 PIN VACUUM	11,79	1	11,79		
				<b>TOTAL</b>	<b>15,33</b>	<b>1</b>	<b>15,33</b>
	<b>W10</b>	322C120H01	31,67	1	31,67		
		44 SKT SUB-D	7,722	1	7,722		
		44 PIN SUB-D	4,813	1	4,813		
		<b>TOTAL</b>			<b>44,205</b>	<b>2</b>	<b>88,41</b>
	<b>W11</b>	78 SKT SUB-D	10,356	1	10,356		
		78 PIN SUB-D	9,457	1	9,457		
		26 PIN SUB-D	3,692	1	3,692		
		<b>TOTAL</b>			<b>23,505</b>	<b>2</b>	<b>47,01</b>
	<b>W12</b>	25 SKT Micro-D	176,78	1	176,78		
		CN100	0,186	4	0,744		
		PIN CN100	0,113	8	0,904		
		FORK TERMINAL	0,33	8	2,64		
		<b>TOTAL</b>			<b>181,068</b>	<b>1</b>	<b>181,068</b>
	<b>W13</b>	M80-1010498S	1,85	1	1,85		
		eyelet terminal	0,18	2	0,36		
		<b>TOTAL</b>			<b>2,21</b>	<b>2</b>	<b>4,42</b>
	<b>W15</b>	IEC Two pole	40,04	1	40,04		
		FORK SKT TERMINAL	0,241	3	0,723		
		FORK PIN TERMINAL	0,33	12	3,96		
		<b>TOTAL</b>			<b>44,723</b>	<b>1</b>	<b>44,723</b>
	<b>W34</b>	44 SKT SUB-D	6,86	2	13,72		
		FORK PIN TERMINAL	0,33	8	2,64		
		<b>TOTAL</b>			<b>16,36</b>	<b>1</b>	<b>16,36</b>
						<b>TOTAL</b>	<b>5015,26</b>

Figure 6.4 – CABLES INT components price

Now, with all the components from the frontal panel of the EIM BOX selected, the price is calculated, as the following one:

6

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<b>PIECE</b>	<b>PRICE</b>
<b>VOLTMETER 5V</b>	54,9
<b>VOLTMETER 3,3V</b>	54,9
<b>FUSE 1</b>	3,906
<b>FUSE 2</b>	3,906
<b>VOLTMETER 12V</b>	50,66
<b>VOLTMETER 12V</b>	50,66
<b>ETHERNET CONNECTOR</b>	53,69
<b>USB CONNECTOR</b>	20,19
<b>TOTAL</b>	<b>292,812</b>

**Figure 6.5** – *EIM BOX frontal panel components price*

Then, all the prices from the wires, labels and braided sleeves are calculated, like in the following pictures:

6

	AWG14		AWG16		AWG22		AWG24		AWG26		Electric Grid PVC
	PER CABLE	QUANTITY	PER CABLE	QUANTITY	PER CABLE	QUANTITY	PER CABLE	QUANTITY	PER CABLE	QUANTITY	
CABLES EXT											
W01	2	0	2	0	2	1356	2	0	2	744	0
W03	2	0	2	0	2	0	2	0	2	3,6	0
W05/W06	24	0	24	0	24	0	24	0	1,8	3,6	0
W08	2	0	2	0	2	89,2	2	0	3,8	24	91,2
W50	1	0	1	0	1	0	1	0	1	0	0
CABLES INT											
W09	1	0	1	0	1	0,6	1	0	1	0	0
W10	2	0	2	0	2	0	2	0	37,2	2	74,4
W11	2	0,4	2	3,4	2	189,2	2	0	2	0	0
W12	1	0	1	0	1	0	1	23,725	1	0	0
W13	2	0	2	0	2	0	2	0	2	0	0
W15	1	0	1	0	1	0	1	0,5	1	0	0
W34	1	0	1	6,392	1	13,2	1	13,2	1	1	175,43
<b>TOTAL</b>		0,4		9,792		1648,2		24,725		913,2	175,43

Figure 6.6 – Total quantity of wire used

CABLE	QUANTITY	PRICE PER METER	TOTAL
AWG14	0,4	3,26	1,304
AWG16	9,792	1,65	16,1568
AWG22	1648,2	0,74	1219,668
AWG24	24,725	0,36	8,901
AWG26	913,2	0,5	456,6
<b>TOTAL</b>			<b>1702,6298</b>

Figure 6.7 – Total wire price

	TMS-SCE-2X-1K-3/32	TMS-SCE-2X-1K-1/8	TMS-SCE-2X-1K-3/16	TMS-SCE-2X-1K-1/4	TMS-SCE-2X-1K-3/8	TMS-SCE-2X-1K-1/2	TMS-SCE-2X-1K-3/4	TMS-SCE-1K-1-2.0
	PER CABLE QUANTITY TOTAL	PER CABLE QUANTITY TOTAL	PER CABLE QUANTITY TOTAL	PER CABLE QUANTITY TOTAL	PER CABLE QUANTITY TOTAL	PER CABLE QUANTITY TOTAL	PER CABLE QUANTITY TOTAL	PER CABLE QUANTITY TOTAL
CABLES EXT								
W01	2	2	2	2	2	2	2	2
W03	0	0	0	0	0	0	0	0
W05/W06	24	24	24	24	24	24	24	24
W08	2	2	2	2	2	2	2	2
W50	1	1	1	1	1	1	1	1
CABLES INT								
W09	3	1	1	1	1	1	1	1
W10	2	2	2	2	2	2	2	2
W11	2	2	2	2	2	2	2	2
W12	12	1	12	1	1	1	1	1
W13	2	2	2	2	2	2	2	2
W15	1	1	1	1	1	1	1	1
W34	1	14	1	1	1	1	1	1
<b>TOTAL</b>	<b>15</b>	<b>70</b>	<b>12</b>	<b>72</b>	<b>6</b>	<b>15</b>	<b>30</b>	<b>16</b>

Figure 6.8 – Total quantity of labels used

LABEL	QUANTITY	PRICE PER 1000 UNITS	TOTAL
TMS-SCE-2X-1K-3/32	15	267,71	4,01565
TMS-SCE-2X-1K-1/8	70	397,21	27,8047
TMS-SCE-2X-1K-3/16	12	343,5	4,122
TMS-SCE-2X-1K-1/4	72	430,14	30,97008
TMS-SCE-2X-1K-3/8	6	831,41	4,98846
TMS-SCE-2X-1K-1/2	15	2345	35,175
TMS-SCE-2X-1K-3/4	30	1455	43,65
TMS-SCE-1K-1-2.0	16	1298	20,768
<b>TOTAL</b>			<b>171,49389</b>

Figure 6.9 – Labels price

	GRP-110-1/8			GRP-110-1/4			GRP-110-1/2			GRP-110-3/4		
	PER CABLE	QUANTITY	TOTAL	PER CABLE	QUANTITY	TOTAL	PER CABLE	QUANTITY	TOTAL	PER CABLE	QUANTITY	TOTAL
CABLES EXT												
W01		2	0		2	0		9	2	18	2	18
W03		2	0		2	0		0	2	0	2	0
W05/W06	0,3	24	7,2	0,1	24	2,4			24	0	24	0
W08	2,7	2	5,4		2	0			2	0	2	0,8
W50		1	0		1	0			1	0	1	0
<b>TOTAL</b>			12,6			2,4				18		18,8

Figure 6.10 – Total quantity of braided sleeve used

SLEEVE	QUANTITY	PRICE PER 30,48M	TOTAL
GRP-110-1/8	12,6	59,13	24,4435039
GRP-110-1/4	2,4	80,74	6,35748031
GRP-110-1/2	18	162,92	96,2125984
GRP-110-3/4	18,8	226,65	139,797244
		<b>TOTAL</b>	<b>266,81083</b>

Figure 6.11 – Braided sleeve price



Now, all the prices calculated are sum, and it is obtained the following total price.

<b>COMPONENT</b>	<b>PRICE</b>
CONNECTORS ANS OTHERS	4934,88
CABLE	1702,6298
LABEL	171,49389
SLEEVES	266,810827
Electric Grid PVC	175,43
<b>TOTAL</b>	<b>7251,2445</b>

**Figure 6.12** – *Total EGSE price*

**6**

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