UNIVERSIDAD DE VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

Grado en Ingeniería Eléctrica

Control sincronizado de dos motores síncronos de diferentes características mediante LabVIEW.

ANEXOS

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Valladolid, Julio de 2021

1. Datasheet IRAMY20UP60B:

PD-96955 Rev.C

International
IOR Rectifier

IRAMY20UP60B
iMOTION™ Series
20A, 600V
with Internal Shunt Resistor

Integrated Power Hybrid IC for
Appliance Motor Drive Applications.

Description

International Rectifier's IRAMY20UP60B is a 20A, 600V Integrated Power Hybrid IC with Internal Shunt Resistor for Appliance Motor Drives applications such as air conditioning systems and compressor drivers as well as for light industrial application. IR's technology offers an extremely compact, high performance AC motor-driver in a single isolated package to simplify design.
This advanced HIC is a combination of IR's low $V_{CE(on)}$ Non Punch-Through IGBT technology and the industry benchmark 3-Phase high voltage, high speed driver in a fully isolated thermally enhanced package.
A built-in temperature monitor and over-current and over-temperature protections, along with the short-circuit rated IGBTs and integrated under-voltage lockout function, deliver high level of protection and fail-safe operation. Using a newly developed single in line package (SiP3) with heatspreader for the power die along with full transfer mold structure minimizes PCB space and resolves isolation problems to heatsink.
UL certified.

Features

- Integrated Gate Drivers
- Temperature Monitor and Protection
- Overcurrent shutdown
- Fully Isolated Package
- Low VCE (on) Non Punch Through IGBT Technology.
- Undervoltage lockout for all channels
- Matched propagation delay for all channels
- 5V Schmitt-triggered input logic
- Cross-conduction prevention logic
- Lower di/dt gate driver for better noise immunity
- Motor Power range 0.75~2.2kW / 85~253 Vac
- Isolation 2000V_{RMS} min
- UL Certificate Number: E252584

Absolute Maximum Ratings

Parameter	Description	Value	Units
V_{CES} / V_{RRM}	IGBT/Diode Blocking Voltage	600	V
V^+	Positive Bus Input Voltage	450	
I_O @ T_C=25°C	RMS Phase Current (Note 1)	20	A
I_O @ T_C=100°C	RMS Phase Current (Note 1)	10	
I_O	Pulsed RMS Phase Current (Note 2)	40	
F_{PWM}	PWM Carrier Frequency	20	kHz
P_D	Power dissipation per IGBT @ T_C =25°C	68	W
V_{ISO}	Isolation Voltage (1min)	2000	V_{RMS}
T_J (IGBT & Diodes)	Operating Junction temperature Range	-40 to +150	°C
T_J (Driver IC)	Operating Junction temperature Range	-40 to +150	
T	Mounting torque Range (M4 screw)	0.7 to 1.17	Nm

Note 1: Sinusoidal Modulation at V^+=400V, T_J=150°C, F_{PWM}=20kHz, Modulation Depth=0.8, PF=0.6, See Figure 3.
Note 2: t_p<100ms; T_C=25°C; F_{PWM}=20kHz. Limited by $I_{BUS-TRIP}$, see Table "Inverter Section Electrical Characteristics"

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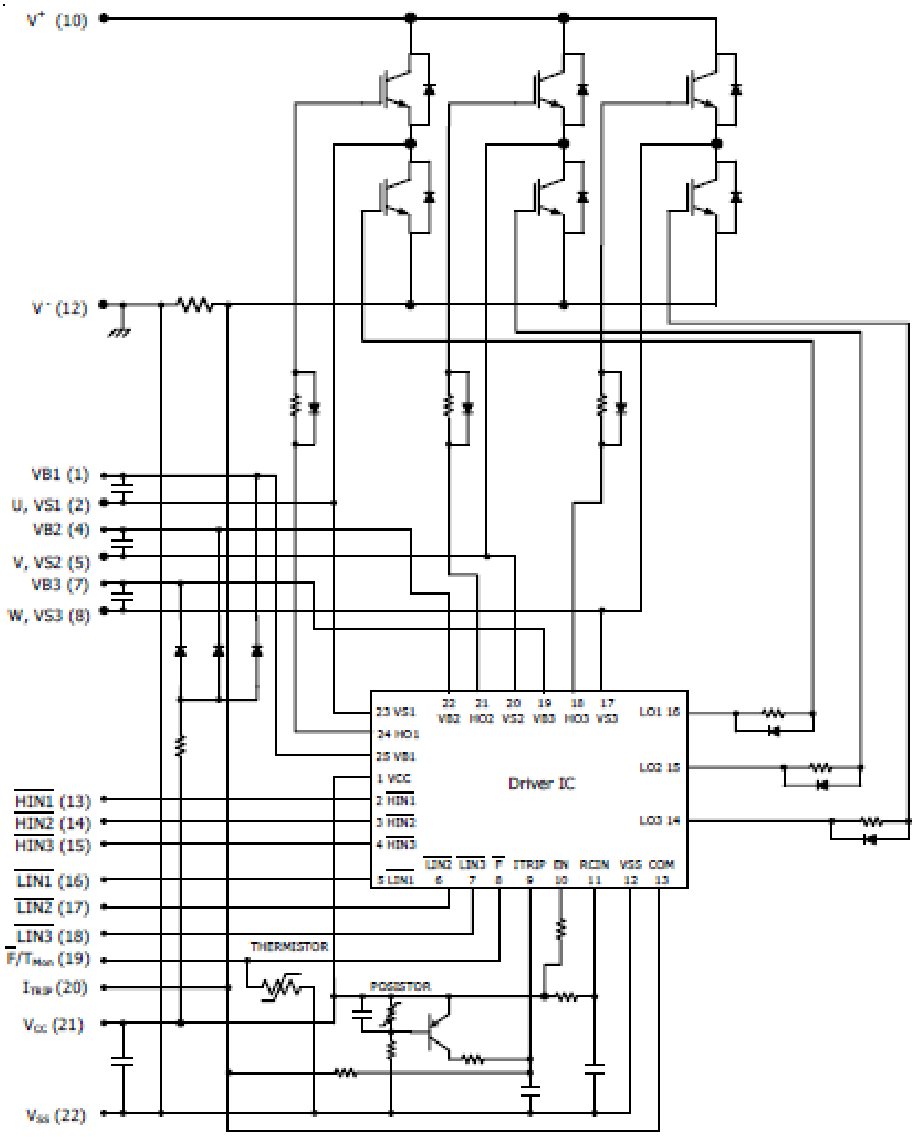
Internal Electrical Schematic - IRAMY20UP60B



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Absolute Maximum Ratings (Continued)

All voltages are absolute referenced to COM/I_{TRIP}.

Symbol	Parameter	Min	Max	Units	Conditions
I_{BDF}	Bootstrap Diode Peak Forward Current	---	4.5	A	t_P= 10ms, T_J = 150°C, T_C=100°C
$P_{BR\ Peak}$	Bootstrap Resistor Peak Power (Single Pulse)	---	25.0	W	t_P=100µs, T_C =100°C ESR / ERJ series
$V_{S1,2,3}$	High side floating supply offset voltage	$V_{B1,2,3}$ - 25	$V_{B1,2,3}$ +0.3	V	
$V_{B1,2,3}$	High side floating supply voltage	-0.3	600	V	
V_{CC}	Low Side and logic fixed supply voltage	-0.3	20	V	
V_{IN}	Input voltage LIN, HIN, I_{Trip}	-0.3	Lower of (V_{SS}+15V) or V_{CC}+0.3V	V	

Inverter Section Electrical Characteristics @T_J= 25°C

Symbol	Parameter	Min	Typ	Max	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{IN}=5V, I_C=250µA
$\Delta V_{(BR)CES}$ / ΔT	Temperature Coeff. Of Breakdown Voltage	---	0.3	---	V/°C	V_{IN}=5V, I_C=1.0mA (25°C - 150°C)
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	---	1.75	2.15	V	I_C=10A, V_{CC}=15V
		---	2.00	2.50		I_C=10A, V_{CC}=15V, T_J=125°C
I_{CES}	Zero Gate Voltage Collector Current	---	5	80	µA	V_{IN}=5V, V^+=600V
		---	80	---		V_{IN}=5V, V^+=600V, T_J=125°C
V_{FM}	Diode Forward Voltage Drop	---	1.9	2.6	V	I_C=10A
		---	1.6	2.3		I_C=10A, T_J=125°C
V_{BDFM}	Bootstrap Diode Forward Voltage Drop	--	--	1.25	V	I_F=1A
		---	---	1.10		I_F=1A, T_J=125°C
R_{BR}	Bootstrap Resistor Value	---	22	---	Ω	T_J=25°C
$\Delta R_{BR}/R_{BR}$	Bootstrap Resistor Tolerance	---	---	±5	%	T_J=25°C
I_{BUS_TRIP}	Current Protection Threshold (positive going)	26	---	34	A	T_J=-40°C to 125°C See Fig. 2

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Inverter Section Switching Characteristics @ T_J= 25°C

Symbol	Parameter	Min	Typ	Max	Units	Conditions
E_{ON}	Turn-On Switching Loss	---	320	460	µJ	I_C=10A, V^+=400V V_{CC}=15V, L=2mH Energy losses include "tail" and diode reverse recovery See CT1
E_{OFF}	Turn-Off Switching Loss	---	175	225		
E_{TOT}	Total Switching Loss	---	495	685		
E_{REC}	Diode Reverse Recovery energy		35	70		
t_{RR}	Diode Reverse Recovery time	---	95	---	ns	
E_{ON}	Turn-On Switching Loss	---	520	680	µJ	I_C=10A, V^+=400V V_{CC}=15V, L=2mH, T_J=125°C Energy losses include "tail" and diode reverse recovery See CT1
E_{OFF}	Turn-off Switching Loss	---	305	385		
E_{TOT}	Total Switching Loss	---	825	1065		
E_{REC}	Diode Reverse Recovery energy	---	50	100		
t_{RR}	Diode Reverse Recovery time	---	125	---	ns	
Q_G	Turn-On IGBT Gate Charge	---	56	84	nC	I_C=15A, V^+=400V, V_{GE}=15V
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T_J=150°C, I_C=10A, V_P=600V V^+= 450V V_{CC}=+15V to 0V See CT3
SCSOA	Short Circuit Safe Operating Area	10	---	---	µs	T_J=150°C, V_P=600V, V^+= 360V, V_{CC}=+15V to 0V See CT2
I_{CSC}	Short Circuit Collector Current	---	140	---	A	T_J=150°C, V_P=600V, t_{SC}<10µs V^+= 360V, V_{GE}=15V V_{CC}=+15V to 0V See CT2

Recommended Operating Conditions Driver Function

The Input/Output logic timing diagram is shown in Figure 1. For proper operation the device should be used within the recommende conditions. All voltages are absolute referenced to COM/I_{TRIP}. The V_S offset is tested with all supplies biased at 15V differential (Note 3)

Symbol	Definition	Min	Max	Units
$V_{B1,2,3}$	High side floating supply voltage	V_S+12	V_S+20	V
$V_{S1,2,3}$	High side floating supply offset voltage	Note 4	450	
V_{CC}	Low side and logic fixed supply voltage	12	20	V
V_{ITRIP}	I_{TRIP} input voltage	V_{SS}	V_{SS}+5	
V_{IN}	Logic input voltage LIN, HIN	V_{SS}	V_{SS}+5	V

Note 3: For more details, see IR21363 data sheet

Note 4: Logic operational for V_s from COM/I_{TRIP}-5V to COM/ITRIP+600V. Logic state held for V_s from COM/ITRIP-5V to COM/ITRIP-V_{BS}.

Static Electrical Characteristics Driver Function

V_{BIAS} (V_{CC}, $V_{BS1,2,3}$)=15V, unless otherwise specified. The V_{IN} and I_{IN} parameters are referenced to COM/I_{TRIP} and are applicable to all six channels. (Note 3)

Symbol	Definition	Min	Typ	Max	Units
V_{IH}	Logic "0" input voltage	3.0	---	---	V
V_{IL}	Logic "1" input voltage	---	---	0.8	V
V_{CCUV+}, V_{BSUV+}	V_{CC} and V_{BS} supply undervoltage positive going threshold	10.6	11.1	11.6	V
V_{CCUV-}, V_{BSUV-}	V_{CC} and V_{BS} supply undervoltage negative going threshold	10.4	10.9	11.4	V
V_{CCUVH}, V_{BSUVH}	V_{CC} and V_{BS} supply undervoltage lock-out hysteresis	---	0.2	---	V
$V_{IN,Clamp}$	Input Clamp Voltage (HIN, LIN, T/I_{TRIP}) I_{IN}=10µA	4.9	5.2	5.5	V
I_{QBS}	Quiescent V_{BS} supply current V_{IN}=0V	---	---	165	µA
I_{QCC}	Quiescent V_{CC} supply current V_{IN}=0V	---	---	3.35	mA
I_{LK}	Offset Supply Leakage Current	---	---	60	µA
I_{IN+}	Input bias current V_{IN}=5V	---	200	300	µA
I_{IN-}	Input bias current V_{IN}=0V	---	100	220	µA
I_{TRIP+}	I_{TRIP} bias current V_{ITRIP}=5V	---	30	100	µA
I_{TRIP-}	I_{TRIP} bias current V_{ITRIP}=0V	---	0	1	µA
V(I_{TRIP})	I_{TRIP} threshold Voltage	440	490	540	mV
V(I_{TRIP},HYS)	I_{TRIP} Input Hysteresis	---	70	---	mV

Dynamic Electrical Characteristics

Driver only timing unless otherwise specified.)

Symbol	Parameter	Min	Typ	Max	Units	Conditions
T_{ON}	Input to Output propagation turn-on delay time (see fig.11)	---	590	---	ns	V_{CC}=V_{BS}= 15V, I_C=10A, V^+=400V
T_{OFF}	Input to Output propagation turn-off delay time (see fig. 11)	---	700	---	ns	
T_{FLIN}	Input Filter time (HIN, LIN)	100	200	---	ns	V_{IN}=0 & V_{IN}=5V
$T_{BLT-Trip}$	I_{TRIP} Blancking Time	100	150		ns	V_{IN}=0 & V_{IN}=5V
D_T	Dead Time (V_{BS}=V_{DD}=15V)	220	290	360	ns	V_{BS}=V_{CC}=15V
M_T	Matching Propagation Delay Time (On & Off)	---	40	75	ns	V_{CC}= V_{BS}= 15V, external dead time> 400ns
T_{ITrip}	I_{Trip} to six switch to turn-off propagation delay (see fig. 2)	---	---	1.75	µs	V_{CC}=V_{BS}= 15V, I_C=10A, V^+=400V
$T_{FLT-CLR}$	Post I_{Trip} to six switch to turn-off clear time (see fig. 2)	---	7.7	---	ms	T_C = 25°C
		---	6.7	---		T_C = 100°C

Thermal and Mechanical Characteristics

Symbol	Parameter	Min	Typ	Max	Units	Conditions
$R_{th(J-C)}$	Thermal resistance, per IGBT	---	1.6	1.8	°C/W	Flat, greased surface. Heatsink compound thermal conductivity 1W/mK
$R_{th(J-C)}$	Thermal resistance, per Diode	---	2.2	3		
$R_{th(C-S)}$	Thermal resistance, C-S	---	0.1	---		
C_D	Creepage Distance	3.5	---	---	mm	See outline Drawings

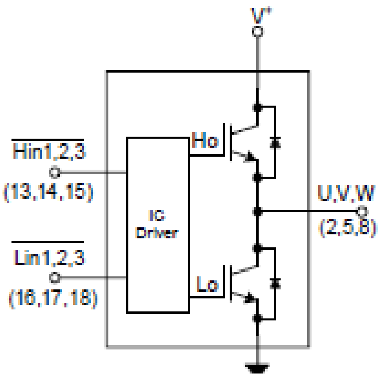
Internal Current Sensing Resistor - Shunt Characteristics

Symbol	Parameter	Min	Typ	Max	Units	Conditions
R_{Shunt}	Resistance	16.8	17.0	17.2	mΩ	T_C = 25°C
T_{Coeff}	Temperature Coefficient	0	---	200	ppm/°C	
P_{Shunt}	Power Dissipation	---	---	4.5	W	-40°C< T_C <100°C
T_{Range}	Temperature Range	-40	---	125	°C	

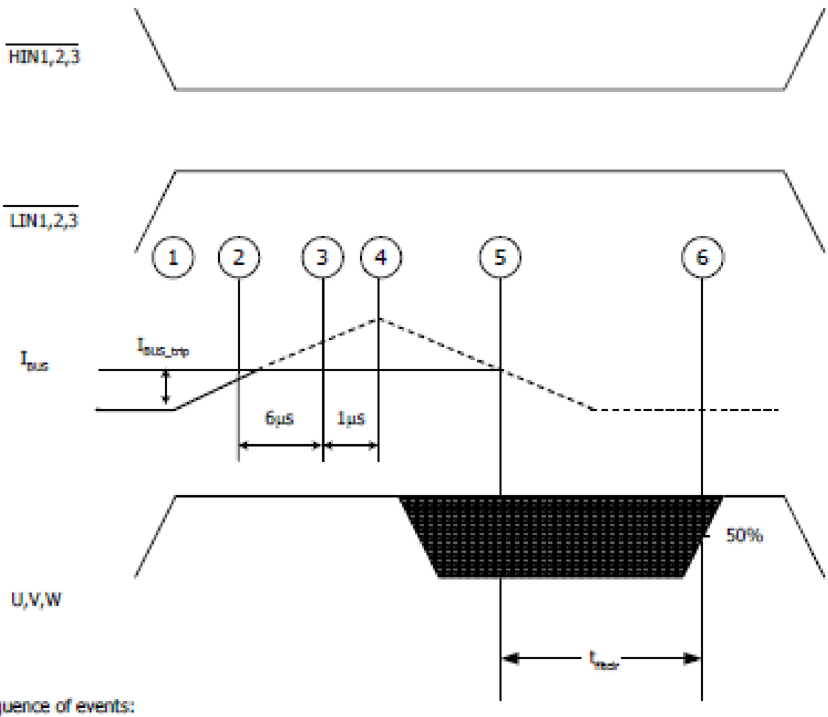
Internal NTC - Thermistor Characteristics

Parameter	Definition	Min	Typ	Max	Units	Conditions
R_{25}	Resistance	97	100	103	kΩ	T_C = 25°C
R_{125}	Resistance	2.25	2.52	2.80	kΩ	T_C = 125°C
B	B-constant (25-50°C)	4165	4250	4335	k	$R_2 = R_1 e^{[B(1/T2 - 1/T1)]}$
Temperature Range		-40		125	°C	
Typ. Dissipation constant			1		mW/°C	T_C = 25°C

Input-Output Logic Level Table



I_{TRIP}	$\overline{HIN1,2,3}$	$\overline{LIN1,2,3}$	U,V,W
0	0	1	V^+
0	1	0	0
0	1	1	X
1	X	X	X



Sequence of events:
1-2) Current begins to rise
2) Current reaches I_{BUS_Trip} level
2-3) Current is higher than I_{BUS_Trip} for at least 6µs. This value is the worst-case condition with very low over-current. In case of high current (short circuit), the actual delay will be smaller.
3-4) Delay between driver identification of over-current condition and disabling of all outputs
4) Current starts decreasing, eventually reaching 0
5) Current goes below I_{BUS_trip}, the driver starts its auto-reset sequence
6) Driver is automatically reset and normal operation can resume (over-current condition must be removed by the time the drivers automatically resets itself)

Figure 2. I_{Trip} Timing Waveform

Note 5: The shaded area indicates that both high-side and low-side switches are off and therefore the half-bridge output voltage would be determined by the direction of current flow in the load.

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Module Pin-Out Description

Pin	Name	Description
1	V_{B1}	High Side Floating Supply Voltage 1
2	U, V_{S1}	Output 1 - High Side Floating Supply Offset Voltage
3	NA	none
4	V_{B2}	High Side Floating Supply voltage 2
5	V,V_{S2}	Output 2 - High Side Floating Supply Offset Voltage
6	NA	none
7	V_{B3}	High Side Floating Supply voltage 3
8	W,V_{S3}	Output 3 - High Side Floating Supply Offset Voltage
9	NA	none
10	V+	Positive Bus Input Voltage
11	NA	none
12	V-	Negative Bus Input Voltage
13	$\overline{H_{IN1}}$	Logic Input High Side Gate Driver - Phase 1
14	$\overline{H_{IN2}}$	Logic Input High Side Gate Driver - Phase 2
15	$\overline{H_{IN3}}$	Logic Input High Side Gate Driver - Phase 3
16	$\overline{L_{IN1}}$	Logic Input Low Side Gate Driver - Phase 1
17	$\overline{L_{IN2}}$	Logic Input Low Side Gate Driver - Phase 2
18	$\overline{L_{IN3}}$	Logic Input Low Side Gate Driver - Phase 3
19	$\overline{Fault}/T_{MON}$	Temperature Monitor and Fault Function
20	I_{TRIP}	Current Monitor
21	V_{CC}	+15V Main Supply
22	V_{SS}	Negative Main Supply

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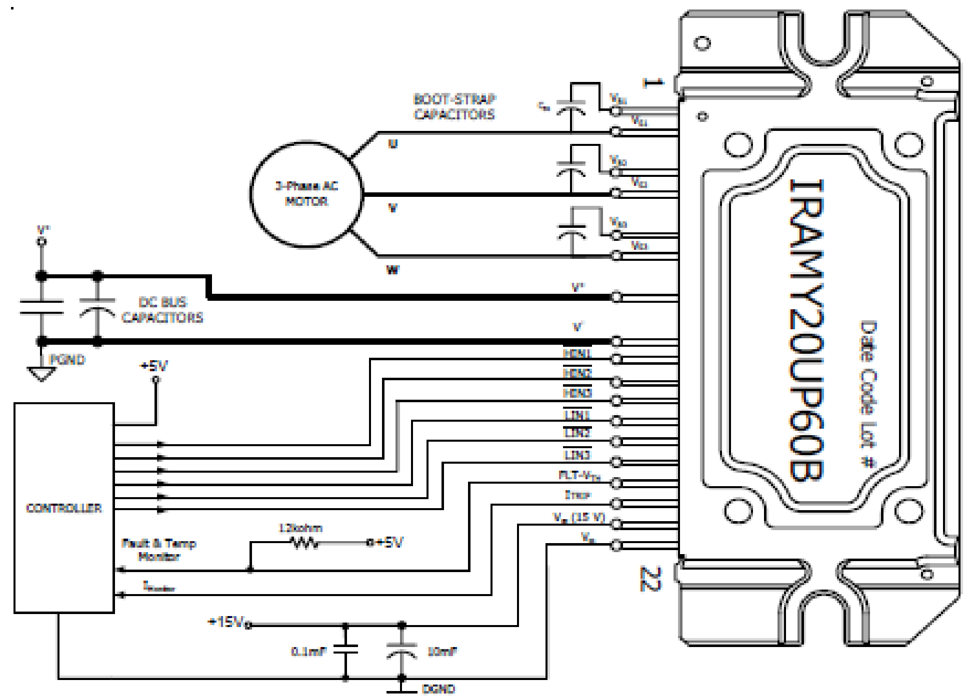
Typical Application Connection IRAMY20UP60B



1. Electrolytic bus capacitors should be mounted as close to the module bus terminals as possible to reduce ringing and EMI problems. Additional high frequency ceramic capacitor mounted close to the module pins will further improve performance.

2. In order to provide good decoupling between V_{CC}-V_{SS} and $V_{B1,2,3}$-$V_{S1,2,3}$ terminals, the capacitors shown connected between these terminals should be located very close to the module pins. Additional high frequency capacitors, typically 0.1µF, are strongly recommended.

3. Value of the boot-strap capacitors depends upon the switching frequency. Their selection should be made based on IR design tip DN 98-2a, application note AN-1044 or Figure 9. Bootstrap capacitor value must be selected to limit the power dissipation of the internal resistor in series with the V_{CC}. (see maximum ratings Table on page 3).

4. Current sense signal can be obtained from pin 20 and pin 22. Care should be taken to avoid having inverter current flowing through pin 22 to mantain required current measurement accuracy

5. After approx. 8ms the FAULT is reset. (see Dynamic Characteristics Table on page 5).

6. PWM generator must be disabled within Fault duration to guarantee shutdown of the system, overcurrent condition must be cleared before resuming operation.

7. Fault/Temp Monitor pin must be pulled-up to +5V.

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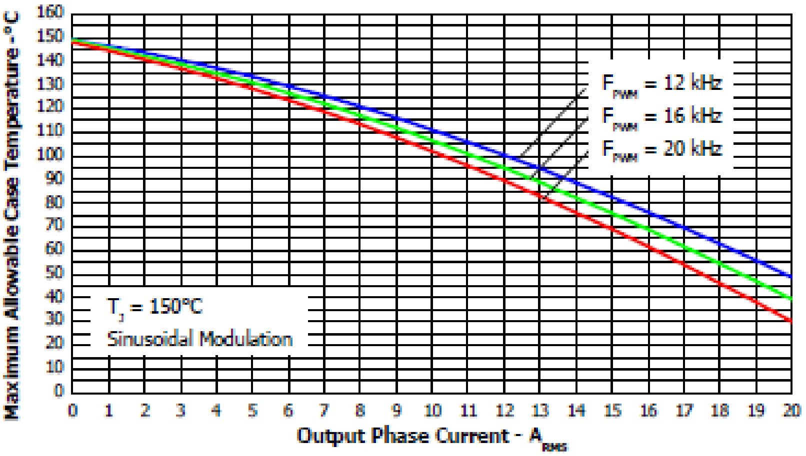


Figure 7. Maximum Allowable Case temperature vs. Output RMS Current per Phase

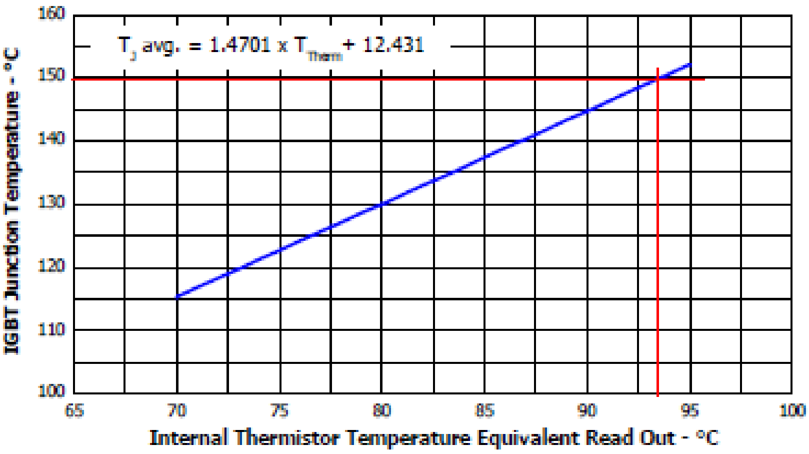
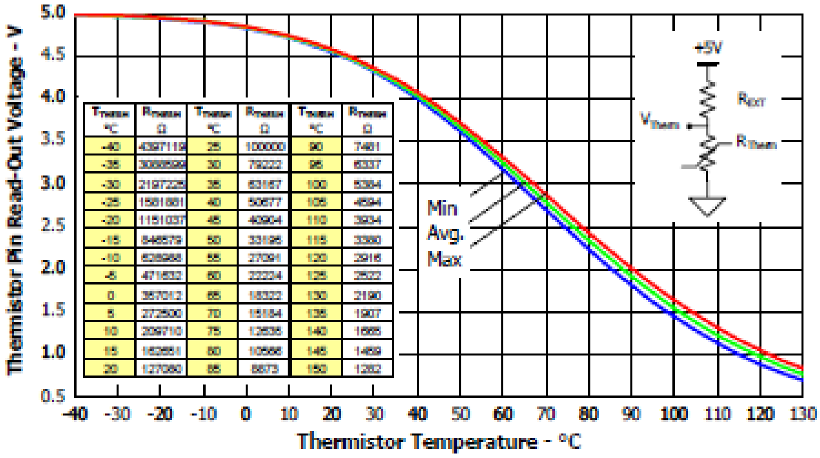


Figure 8. Estimated Maximum IGBT Junction Temperature vs. Thermistor Temperature



T_{THERM} °C	R_{THERM} Ω	T_{THERM} °C	R_{THERM} Ω	T_{THERM} °C	R_{THERM} Ω
-40	4397119	25	100000	90	7481
-35	3088599	30	79222	95	6337
-30	2197225	35	63167	100	5384
-25	1581881	40	50677	105	4594
-20	1151037	45	40904	110	3934
-15	846579	50	33195	115	3380
-10	628988	55	27091	120	2916
-5	471632	60	22224	125	2522
0	357012	65	18322	130	2190
5	272500	70	15184	135	1907
10	209710	75	12635	140	1665
15	162651	80	10566	145	1459
20	127080	85	8873	150	1282

Figure 9. Thermistor Readout vs. Temperature (12kohm pull-up resistor, 5V) and Nominal Thermistor Resistance values vs. Temperature Table.

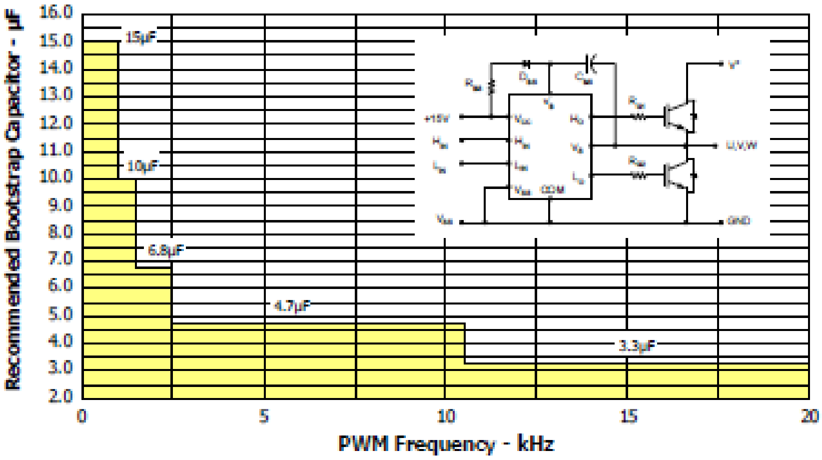


Figure 10. Recommended Bootstrap Capacitor Value vs. Switching Frequency

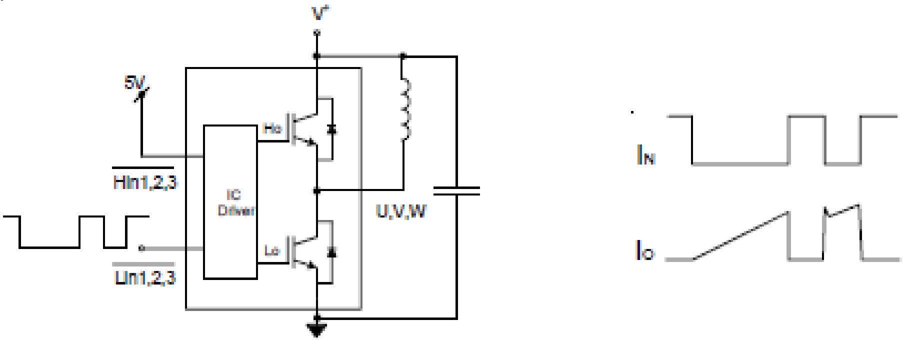


Figure CT1. Switching Loss Circuit

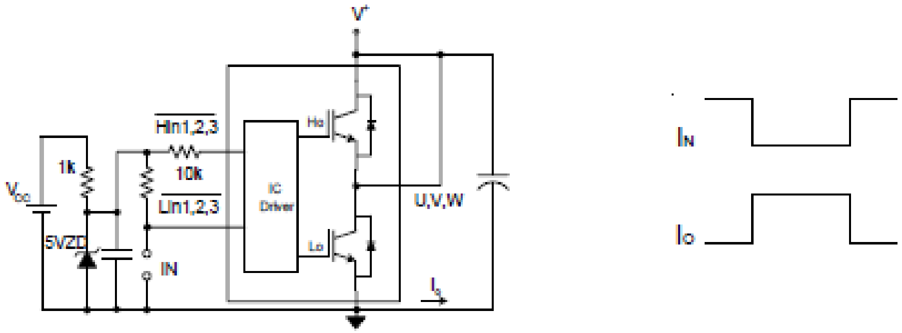


Figure CT2. S.C.SOA Circuit

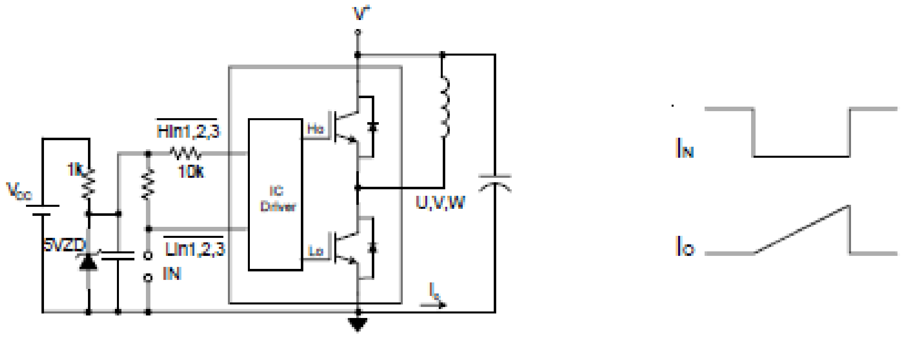
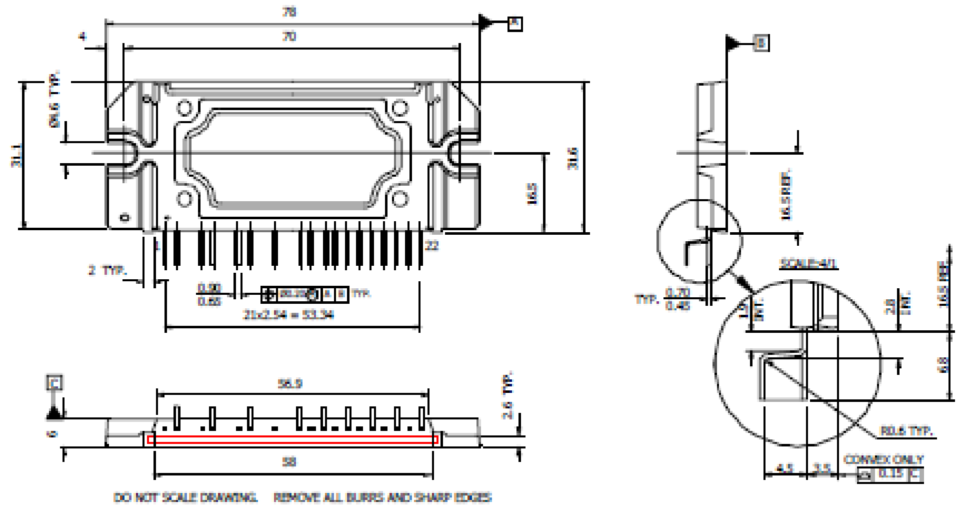


Figure CT3. R.B.SOA Circuit

Package Outline



Standard Pin leadforming option

For mounting instruction see AN-1049

Notes:

Dimensions in mm

1- Marking for pin 1 identification

2- Product Part Number

3- Lot and Date code marking

4- Convex only 0.15mm typical

5- Tollerances ±0.5mm, unless otherwise stated

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2. Características Raspberry PI 4:

2 Features

2.1 Hardware

- Quad core 64-bit ARM-Cortex A72 running at 1.5GHz
- 1, 2 and 4 Gigabyte LPDDR4 RAM options
- H.265 (HEVC) hardware decode (up to 4Kp60)
- H.264 hardware decode (up to 1080p60)
- VideoCore VI 3D Graphics
- Supports dual HDMI display output up to 4Kp60

2.2 Interfaces

- 802.11 b/g/n/ac Wireless LAN
- Bluetooth 5.0 with BLE
- 1x SD Card
- 2x micro-HDMI ports supporting dual displays up to 4Kp60 resolution
- 2x USB2 ports
- 2x USB3 ports
- 1x Gigabit Ethernet port (supports PoE with add-on PoE HAT)
- 1x Raspberry Pi camera port (2-lane MIPI CSI)
- 1x Raspberry Pi display port (2-lane MIPI DSI)
- 28x user GPIO supporting various interface options:
  - Up to 6x UART
  - Up to 6x I2C
  - Up to 5x SPI
  - 1x SDIO interface
  - 1x DPI (Parallel RGB Display)
  - 1x PCM
  - Up to 2x PWM channels
  - Up to 3x GPCLK outputs

2.3 Software

- ARMv8 Instruction Set
- Mature Linux software stack
- Actively developed and maintained
  - Recent Linux kernel support
  - Many drivers upstreamed
  - Stable and well supported userland
  - Availability of GPU functions using standard APIs

3 Mechanical Specification

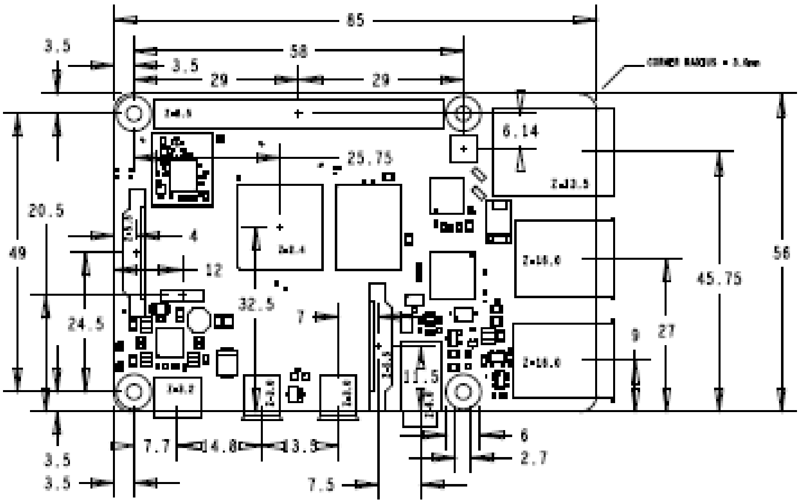

Figure 1: Mechanical Dimensions

4 Electrical Specification

Caution! Stresses above those listed in Table 2 may cause permanent damage to the device. This is a stress rating only; functional operation of the device under these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Raspberry Pi 4 Model B Datasheet
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Symbol	Parameter	Minimum	Maximum	Unit
VIN	5V Input Voltage	-0.5	6.0	V

Table 2: Absolute Maximum Ratings

Please note that VDD_IO is the GPIO bank voltage which is tied to the on-board 3.3V supply rail.

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{IL}	Input low voltage[a]	VDD_IO = 3.3V	-	-	TBD	V
V_{IH}	Input high voltage[a]	VDD_IO = 3.3V	TBD	-	-	V
I_{IL}	Input leakage current	TA = +85°C	-	-	TBD	μA
C_{IN}	Input capacitance	-	-	TBD	-	pF
V_{OL}	Output low voltage[b]	VDD_IO = 3.3V, IOL = -2mA	-	-	TBD	V
V_{OH}	Output high voltage[b]	VDD_IO = 3.3V, IOH = 2mA	TBD	-	-	V
I_{OL}	Output low current[c]	VDD_IO = 3.3V, VO = 0.4V	TBD	-	-	mA
I_{OH}	Output high current[c]	VDD_IO = 3.3V, VO = 2.3V	TBD	-	-	mA
R_{PU}	Pullup resistor	-	TBD	-	TBD	kΩ
R_{PD}	Pulldown resistor	-	TBD	-	TBD	kΩ

[a] Hysteresis enabled
[b] Default drive strength (8mA)
[c] Maximum drive strength (16mA)

Table 3: DC Characteristics

Pin Name	Symbol	Parameter	Minimum	Typical	Maximum	Unit
Digital outputs	t_{rise}	10-90% rise time[a]	-	TBD	-	ns
Digital outputs	t_{fall}	90-10% fall time[a]	-	TBD	-	ns

[a] Default drive strength, CL = 5pF, VDD_IO = 3.3V

Table 4: Digital I/O Pin AC Characteristics

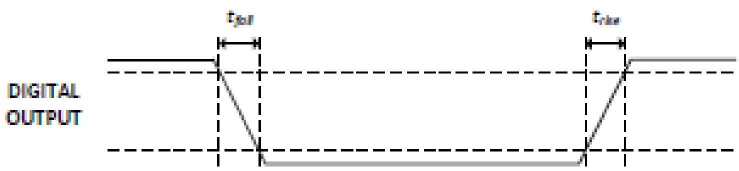


Figure 2: Digital IO Characteristics

4.1 Power Requirements

The Pi4B requires a good quality USB-C power supply capable of delivering 5V at 3A. If attached downstream USB devices consume less than 500mA, a 5V, 2.5A supply may be used.

5 Peripherals

5.1 GPIO Interface

The Pi4B makes 28 BCM2711 GPIOs available via a standard Raspberry Pi 40-pin header. This header is backwards compatible with all previous Raspberry Pi boards with a 40-way header.

5.1.1 GPIO Pin Assignments

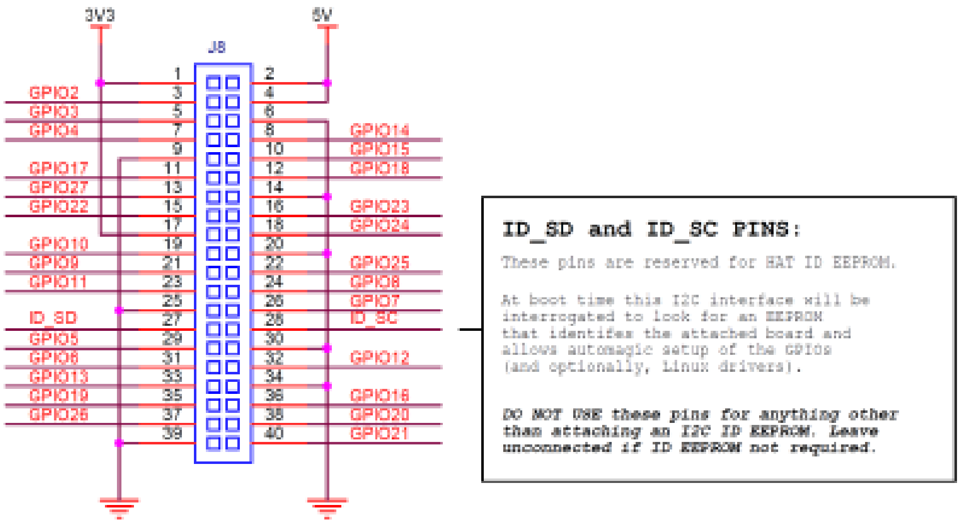


Figure 3: GPIO Connector Pinout

As well as being able to be used as straightforward software controlled input and output (with programmable pulls), GPIO pins can be switched (multiplexed) into various other modes backed by dedicated peripheral blocks such as I2C, UART and SPI.

In addition to the standard peripheral options found on legacy Pis, extra I2C, UART and SPI peripherals have been added to the BCM2711 chip and are available as further mux options on the Pi4. This gives users much more flexibility when attaching add-on hardware as compared to older models.

5.1.2 GPIO Alternate Functions

GPIO	Default Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
0	High	SDA0	SA5	PCLK	SPI3_CE0_N	TXD2	SDA6
1	High	SCL0	SA4	DE	SPI3_MISO	RXD2	SCL6
2	High	SDA1	SA3	LCD_VSYNC	SPI3_MOSI	CTS2	SDA3
3	High	SCL1	SA2	LCD_HSYNC	SPI3_SCLK	RTS2	SCL3
4	High	GPCLK0	SA1	DPI_D0	SPI4_CE0_N	TXD3	SDA3
5	High	GPCLK1	SA0	DPI_D1	SPI4_MISO	RXD3	SCL3
6	High	GPCLK2	SOE_N	DPI_D2	SPI4_MOSI	CTS3	SDA4
7	High	SPI0_CE1_N	SWE_N	DPI_D3	SPI4_SCLK	RTS3	SCL4
8	High	SPI0_CE0_N	SD0	DPI_D4	-	TXD4	SDA4
9	Low	SPI0_MISO	SD1	DPI_D5	-	RXD4	SCL4
10	Low	SPI0_MOSI	SD2	DPI_D6	-	CTS4	SDA5
11	Low	SPI0_SCLK	SD3	DPI_D7	-	RTS4	SCL5
12	Low	PWM0	SD4	DPI_D8	SPI5_CE0_N	TXD5	SDA5
13	Low	PWM1	SD5	DPI_D9	SPI5_MISO	RXD5	SCL5
14	Low	TXD0	SD6	DPI_D10	SPI5_MOSI	CTS5	TXD1
15	Low	RXD0	SD7	DPI_D11	SPI5_SCLK	RTS5	RXD1
16	Low	FL0	SD8	DPI_D12	CTS0	SPI1_CE2_N	CTS1
17	Low	FL1	SD9	DPI_D13	RTS0	SPI1_CE1_N	RTS1
18	Low	PCM_CLK	SD10	DPI_D14	SPI6_CE0_N	SPI1_CE0_N	PWM0
19	Low	PCM_FS	SD11	DPI_D15	SPI6_MISO	SPI1_MISO	PWM1
20	Low	PCM_DIN	SD12	DPI_D16	SPI6_MOSI	SPI1_MOSI	GPCLK0
21	Low	PCM_DOUT	SD13	DPI_D17	SPI6_SCLK	SPI1_SCLK	GPCLK1
22	Low	SD0_CLK	SD14	DPI_D18	SD1_CLK	ARM_TRST	SDA6
23	Low	SD0_CMD	SD15	DPI_D19	SD1_CMD	ARM_RTCK	SCL6
24	Low	SD0_DAT0	SD16	DPI_D20	SD1_DAT0	ARM_TDO	SPI3_CE1_N
25	Low	SD0_DAT1	SD17	DPI_D21	SD1_DAT1	ARM_TCK	SPI4_CE1_N
26	Low	SD0_DAT2	TE0	DPI_D22	SD1_DAT2	ARM_TDI	SPI5_CE1_N
27	Low	SD0_DAT3	TE1	DPI_D23	SD1_DAT3	ARM_TMS	SPI6_CE1_N

Table 5: Raspberry Pi 4 GPIO Alternate Functions

Table 5 details the default pin pull state and available alternate GPIO functions. Most of these alternate peripheral functions are described in detail in the BCM2711 Peripherals Specification document which can be downloaded from the hardware documentation section of the website.

5.1.3 Display Parallel Interface (DPI)

A standard parallel RGB (DPI) interface is available the GPIOs. This up-to-24-bit parallel interface can support a secondary display.

5.1.4 SD/SDIO Interface

The Pi4B has a dedicated SD card socket which suports 1.8V, DDR50 mode (at a peak bandwidth of 50 Megabytes / sec). In addition, a legacy SDIO interface is available on the GPIO pins.

5.2 Camera and Display Interfaces

The Pi4B has 1x Raspberry Pi 2-lane MIPI CSI Camera and 1x Raspberry Pi 2-lane MIPI DSI Display connector. These connectors are backwards compatible with legacy Raspberry Pi boards, and support all of the available Raspberry Pi camera and display peripherals.

5.3 USB

The Pi4B has 2x USB2 and 2x USB3 type-A sockets. Downstream USB current is limited to approximately 1.1A in aggregate over the four sockets.

5.4 HDMI

The Pi4B has 2x micro-HDMI ports, both of which support CEC and HDMI 2.0 with resolutions up to 4Kp60.

5.5 Audio and Composite (TV Out)

The Pi4B supports near-CD-quality analogue audio output and composite TV-output via a 4-ring TRS 'A/V' jack.

The analog audio output can drive 32 Ohm headphones directly.

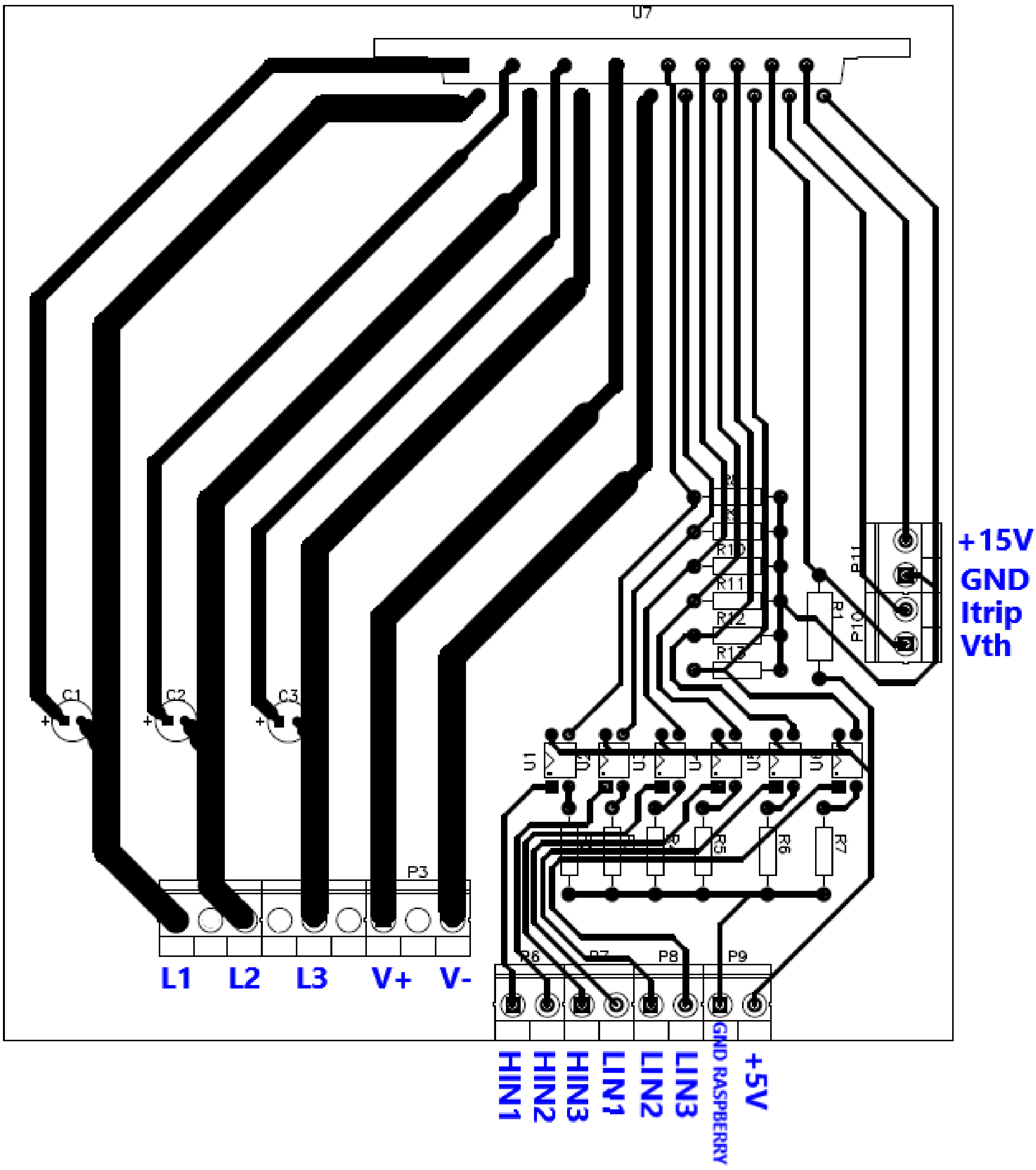
5.6 Temperature Range and Thermals

The recommended ambient operating temperature range is 0 to 50 degrees Celcius.

To reduce thermal output when idling or under light load, the Pi4B reduces the CPU clock speed and voltage. During heavier load the speed and voltage (and hence thermal output) are increased. The internal governor will throttle back both the CPU speed and voltage to make sure the CPU temperature never exceeds 85 degrees C.

The Pi4B will operate perfectly well without any extra cooling and is designed for sprint performance - expecting a light use case on average and ramping up the CPU speed when needed (e.g. when loading a webpage). If a user wishes to load the system continually or operate it at a high termperature at full performance, further cooling may be needed.

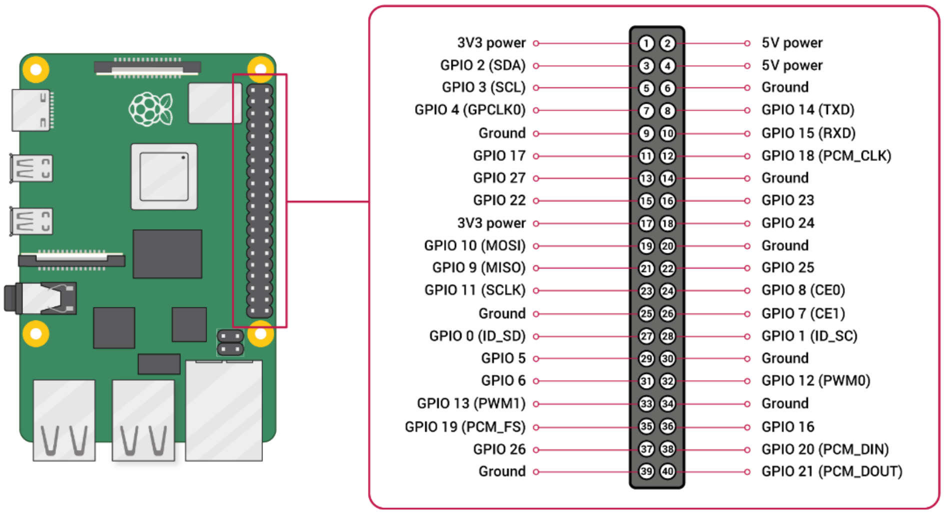
3. Conexiones de la placa de circuito impreso:



NOTA: Las entradas de +5V y +15V han de tener como referencia la entrada GND. También, hay que recordar que la entrada GND Raspberry hace referencia a la toma GND de la Raspberry y, en ningún caso hay que juntarla a la entrada GND.

4. Conexiones de la Raspberry PI:

En la Tabla que se encuentra a continuación, se describe que cables hay que conectar a en cada uno de los pines utilizados de la Raspberry PI y además, si se trata de una entrada o de una salida.



N.º de pin	Tipo	Función
7	Salida	HIN1 del motor 1
11	Salida	LIN1 del motor 1
12	Salida	LIN3 del motor 1
13	Salida	HIN2 del motor 1
15	Salida	LIN2 del motor 1
16	Salida	HIN3 del motor 1
18	Salida	LIN1 del motor 2
22	Salida	HIN1 del motor 2
29	Salida	LIN2 del motor 2
31	Salida	HIN3 del motor 2
32	Salida	HIN2 del motor 2
33	Salida	LIN3 del motor 2
35	Entrada	Giro Horario
36	Entrada	Giro Antihorario
37	Entrada	Freno
38	Entrada	Control de Velocidad I
40	Entrada	Control de Velocidad II

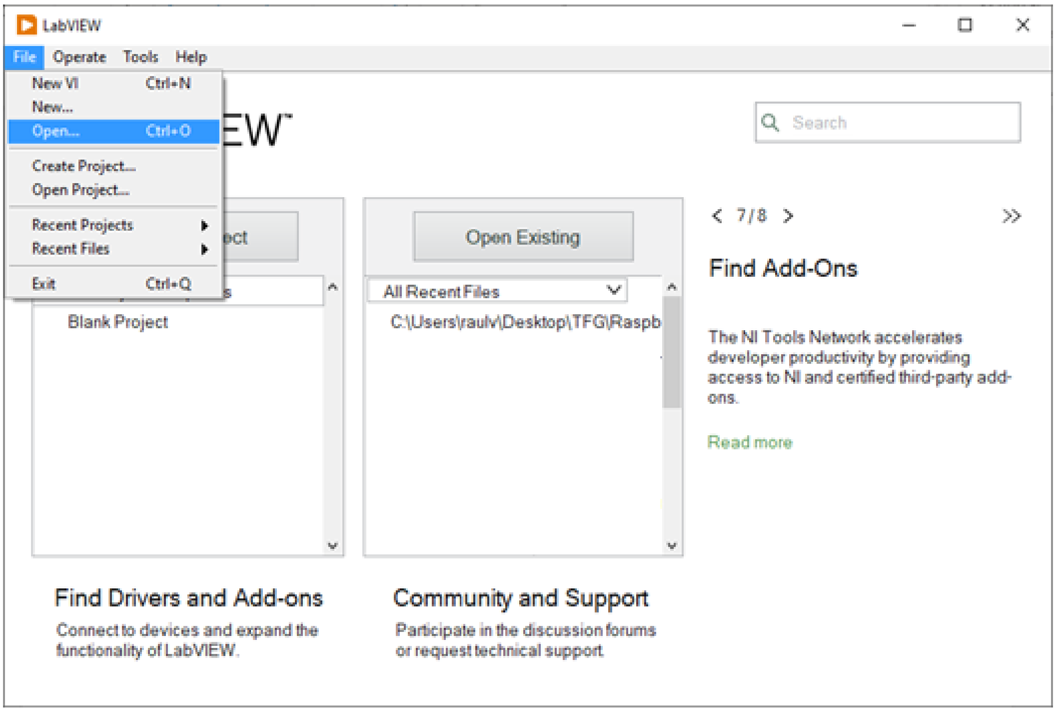
5. Manual de usuario:

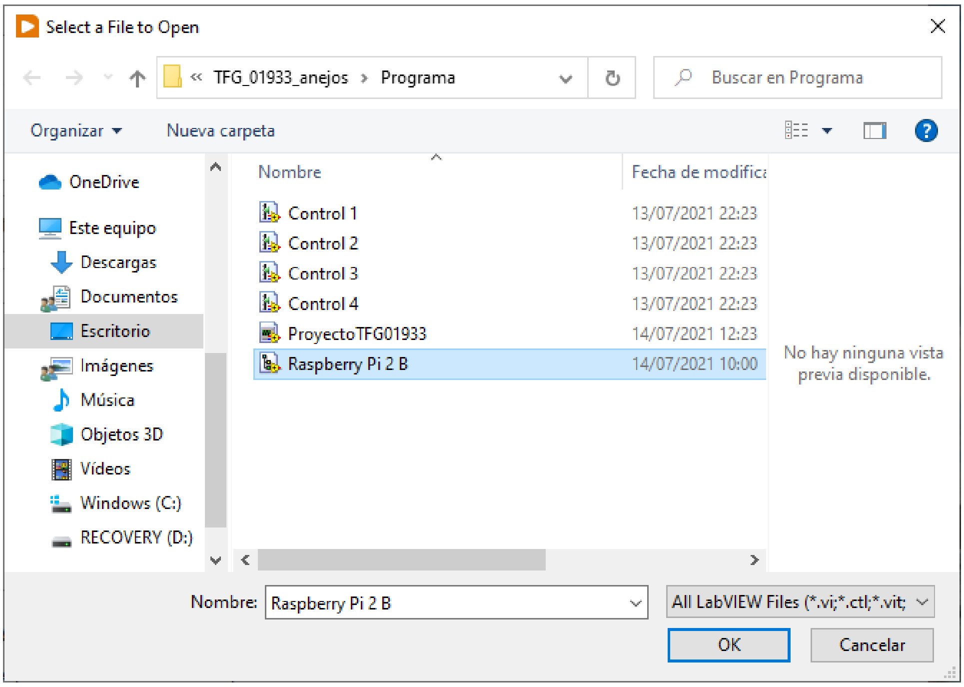
En este manual de usuario se va a tratar de ilustrar de forma sencilla que pasos se han de seguir para conseguir poner en funcionamiento el programa creado y la realización de todas las conexiones de la parte física.

1. Conexión entre el PC y la Raspberry PI.

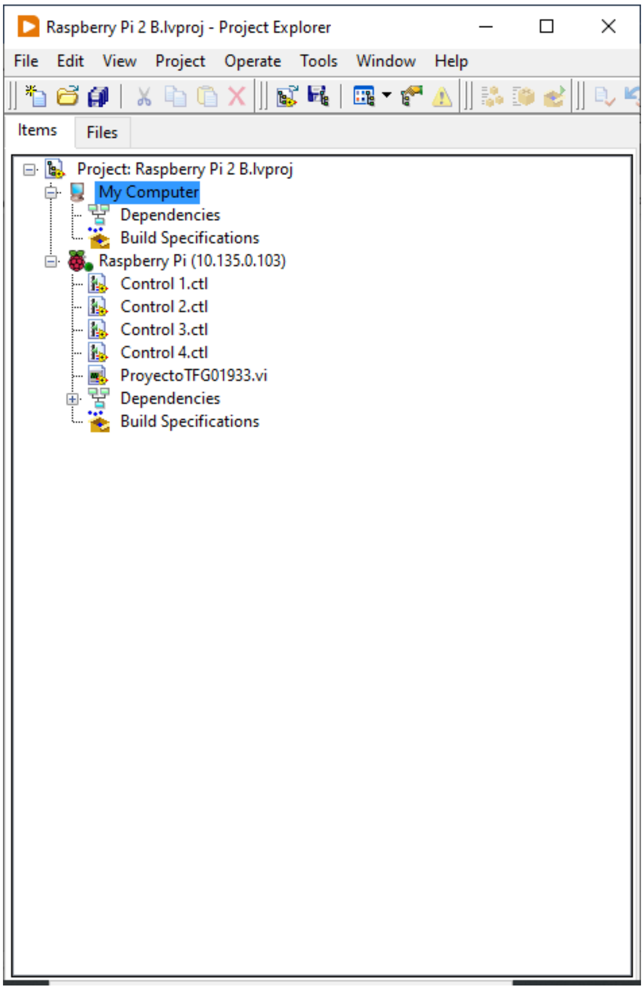
En primer lugar, debemos abrir en el ordenador que se desee emplear la aplicación llamada *"NI LabVIEW 2020 (32-bit)"* o superior, que deberá de estar instalada previamente, junto con el paquete de Linx destinado a la comunicación con la Raspberry PI.

Una vez abierto LabVIEW, debemos elegir y abrir el proyecto en el que se encuentra nuestra tarjeta (el fichero con el proyecto se encuentra en la carpeta de anexos).

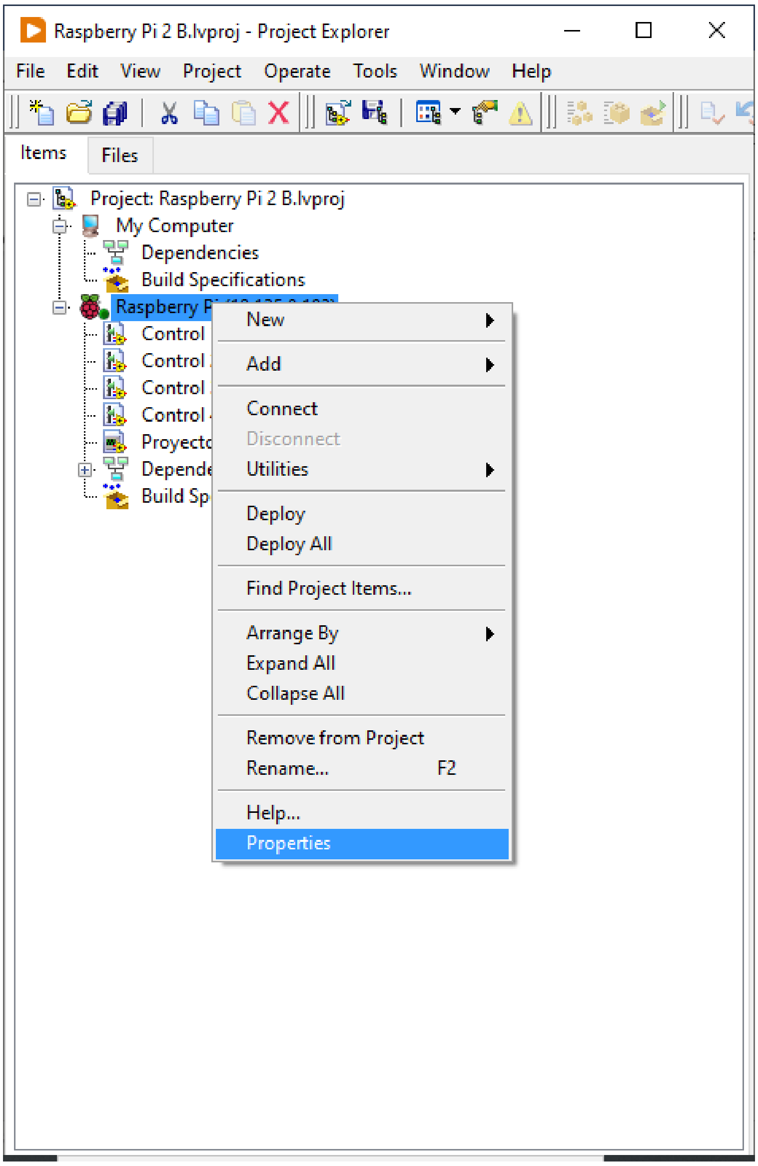




Una vez abierto el proyecto llamado Raspberry Pi 2 B.lvproj, aparece la siguiente pantalla.

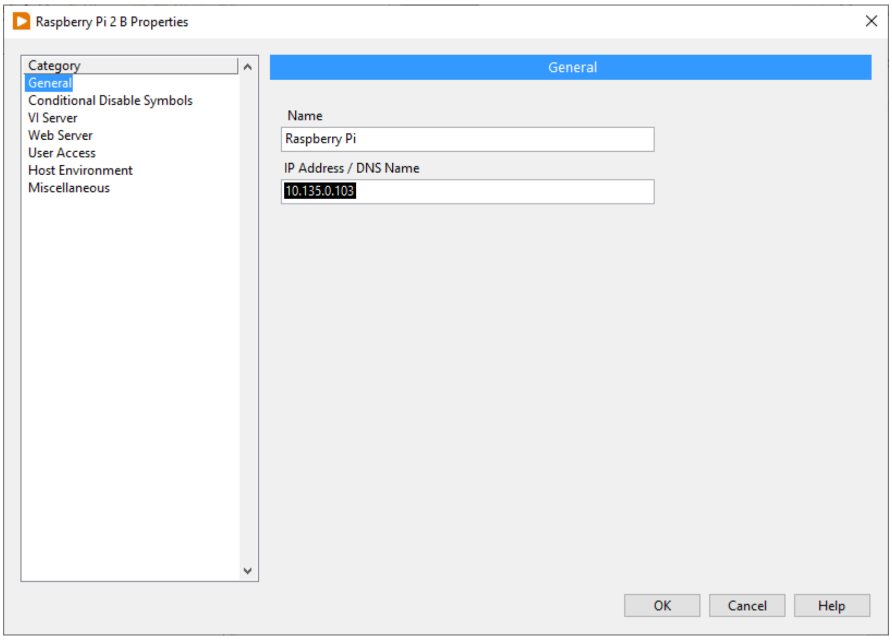


En la parte superior de la imagen, donde aparece "*Raspberry Pi (10.135.0.103)*", hacemos clic con el botón derecho del ratón y pinchamos en "*Propiedades*".

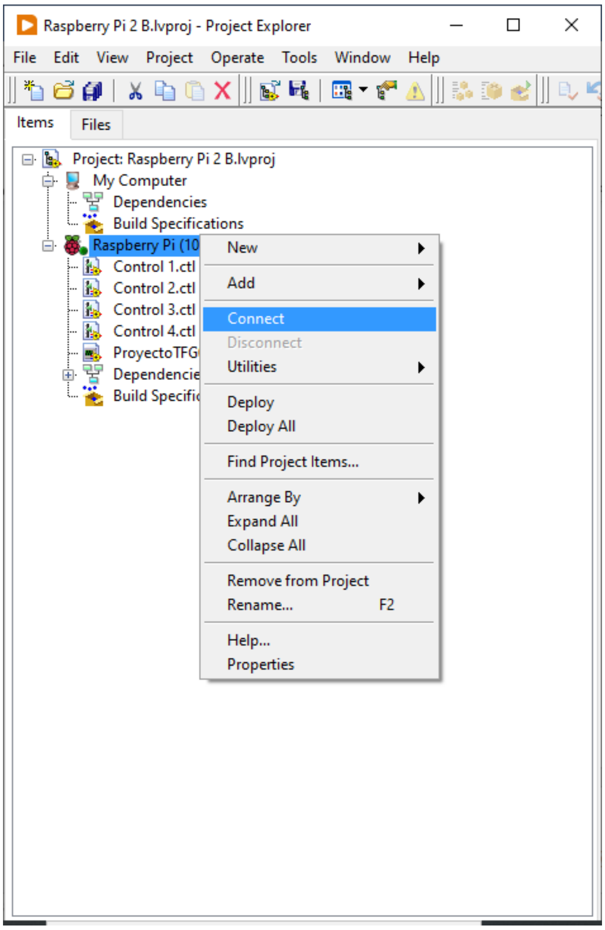


En la nueva ventana que aparece, debemos de cambiar la "*IP Adress/DNS name*" por la dirección IP de la Raspberry PI en el router al que se ha conectado (en la UVa la dirección de la tarjeta es 10.135.0.103). La red en la que se encuentran tanto la Raspberry PI como el ordenador utilizado ha de ser la misma. Esta dirección IP que ha obtenido la tarjeta al conectarse a la red, se obtiene en la barra de comandos de la propia Raspberry PI tecleando el comando ifconfig.

Si el router al que se conectan los dos equipos es el mismo, en lugar de la dirección IP de la tarjeta, se puede poner "raspberrypi".

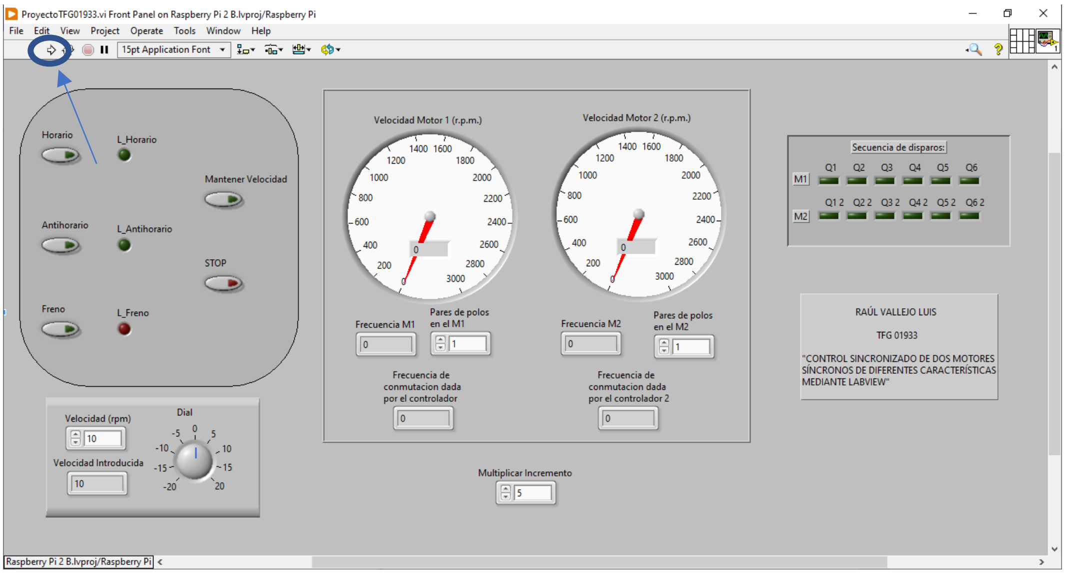


Por último, una vez asignada la nueva dirección de la tarjeta, procedemos a conectarla al ordenador, haciendo clic con el botón derecho del ratón donde aparece *"Raspberry Pi (10.135.0.103)"*, y pinchando en *"Conectar"*. Si el proceso de conexión ha tenido éxito, entonces el led verde oscuro que aparece junto al logo de raspberry se pone en color verde claro.



Realizada correctamente la conexión, el siguiente paso que vamos a llevar a cabo es abrir el programa creado, que se llama “*ProyectoTFG01933.vi*”.

Una vez abierto, aparecerá el panel frontal de la aplicación y para cargarle en la tarjeta, hay que pulsar en la flecha que aparece en la parte superior izquierda.

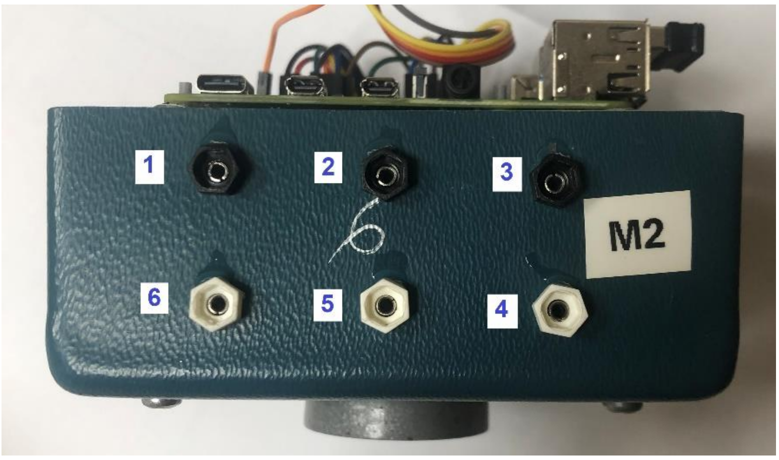


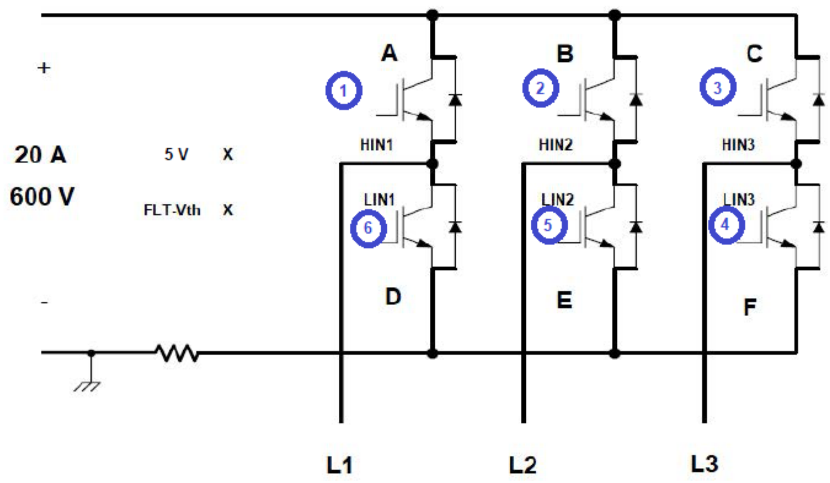
Una vez cargado el programa, estará ejecutándose en la Raspberry PI hasta que se pulse la tecla “*STOP*”.

2. Conexión entre Raspberry PI y el Bastidor.

Para realizar la conexión entre la Raspberry PI y el controlador que se encuentra en el bastidor, se emplean los cables que tienen bananas negras pequeñas.

La conexión eléctrica se lleva a cabo entre los bornes que hay en la caja con imán que contiene la Raspberry PI y los pines del panel del bastidor como se indica en las siguientes imágenes.





Parameter	Description	Value	Parameter	Description	Value
V_{CES}/V_{RRM}	IGBT/Diode Blocking Voltage	600 V	PD	Power Disipation per IGBT (Tc = 25˚C)	68 W
V+	Input Voltage	450 V	VISO	Isolation Voltage (1 min)	2000 VRMS
$I_{0\ (Tc=25^{\circ}C)}$	RMS Phase Current	20 A	Tj (IGBT & Diodes)	Operating Junction Tª Range	-40 to +150 ˚C
$I_{0\ (Tc=100^{\circ}C)}$	IRMS Phase Current	10 A	Tj (Driver IC)	Operating Junction Tª Range	-40 to +150 ˚C
I_0	Pulsed RMS Phase Current	40 A	T	Mounting Torque Range (M4 screw)	0.7 to 1.17 Nm
F_{PWM}	PWR Carrier Frequency	20 kHz	Vcc	Electrical power supply	15 V

Además de estas seis conexiones necesarias por motor, hay que conectar el pin GND de la Raspberry PI con la placa de circuito, por medio de otro cable negro con una banana que se conecta a la parte trasera de la caja que contiene la Raspberry PI.

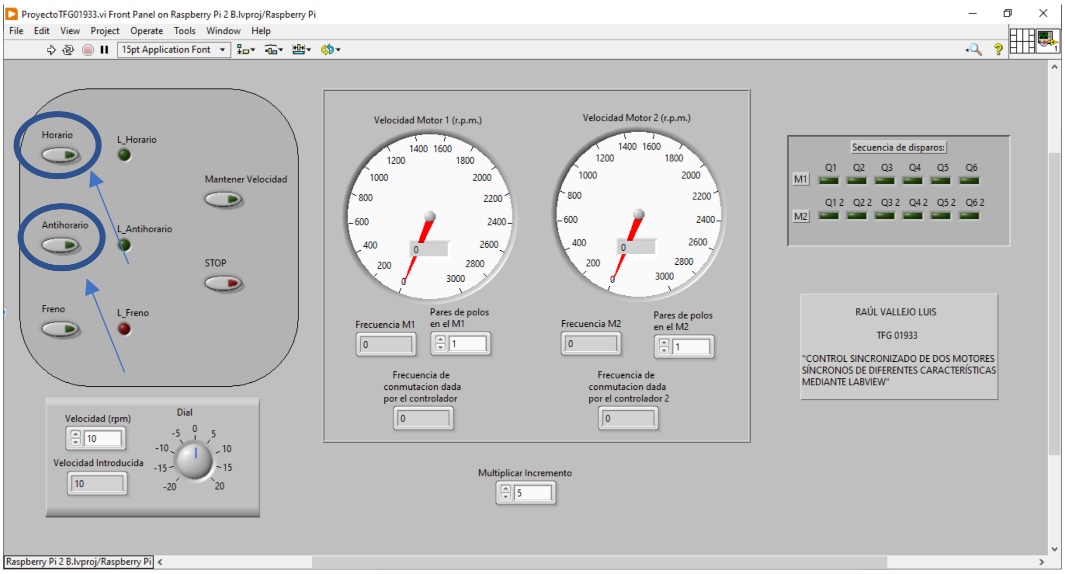
En la caja de la Raspberry PI, esta señalizado con una pegatina que pone "*M1*" o "*M2*" los pines que corresponden con el control del motor 1 y con el control del motor 2 en el programa de LabVIEW.

3. Puesta en marcha de los motores.

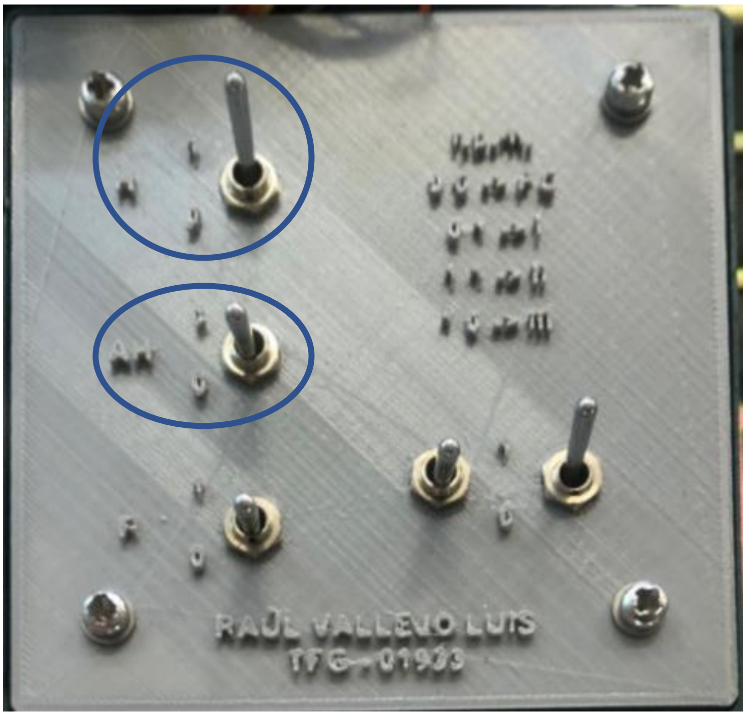
Para la puesta en marcha de los motores, una vez realizados los dos puntos anteriores, debemos conectar la excitación del motor, si este no es de imanes permanentes.

Después, se conecta a las entradas de los paneles del bastidor la alimentación en tensión continua para cada uno de los motores y finalmente, se conecta cada una de las salidas a las fases de los motores con una configuración en estrella.

Para iniciar la marcha se puede activar uno de los pulsadores del panel frontal de giro horario o giro antihorario.

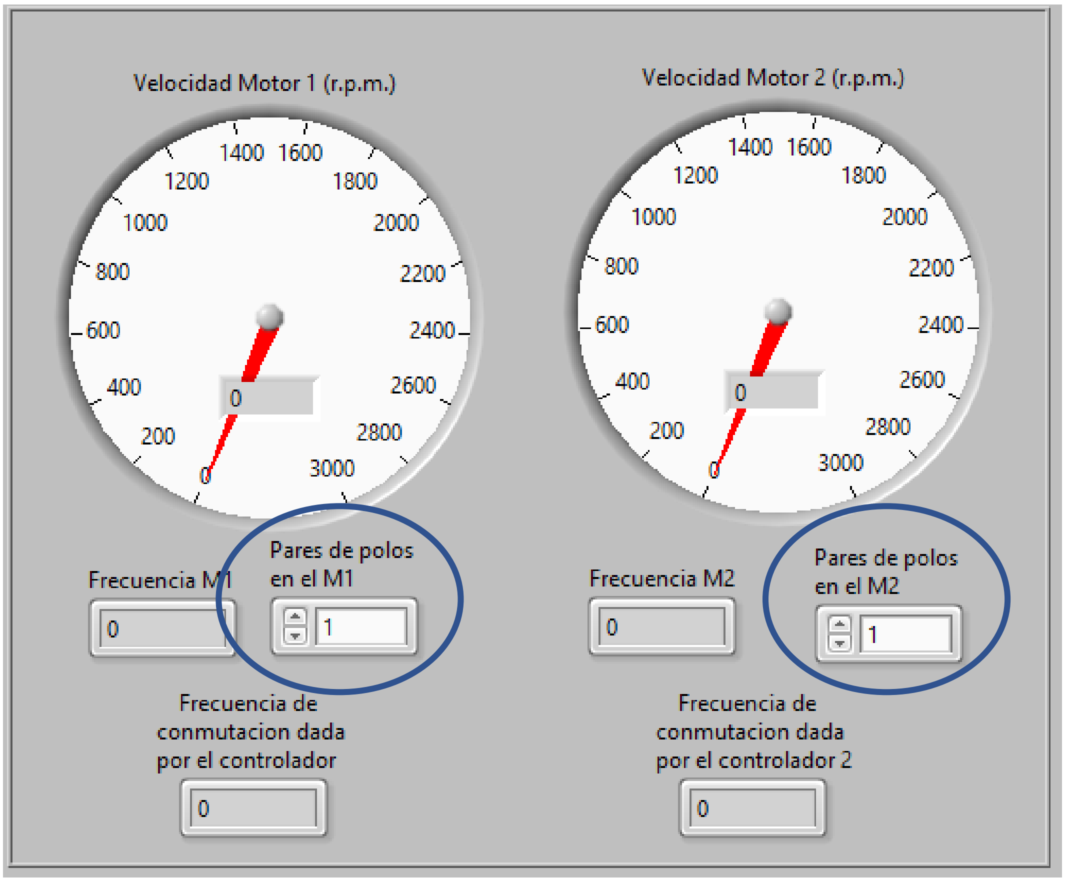


También se puede iniciar la marcha por medio del panel de pulsadores situado de forma contigua a la caja de la Raspberry PI.



Para detener la marcha de los motores, se ha de accionar el pulsador del panel frontal del ordenador llamado "*Freno*" o, el tercer pulsador de la caja de pulsadores.

Para configurar los motores empleados, debemos definir en el panel frontal el número de pares de polos que tiene cada uno. De esta forma, el programa es capaz de saber con qué frecuencia ha de alimentar el motor para que gire a la velocidad definida.



Por último, el control de la velocidad se puede realizar de dos maneras:

- <u>Panel frontal del ordenador</u>:
  Para que esta opción esté habilitada, los dos interruptores correspondientes al control de velocidad de la caja de control que hay en el bastidor han de estar en las posiciones 0 0.

En el panel frontal la referencia de velocidad se introduce en la variable llamada "*Velocidad(rpm)*" y con la ruleta llamada "*Dial*", podremos llevar a cabo la disminución de la velocidad en uno de los motores, mientras que en el otro esta se mantiene constante.

- Caja de pulsadores del bastidor:
  En la caja de control con interruptores, situada en el bastidor, existe una pequeña leyenda que nos indica la velocidad a la que se hace girar el motor dependiendo de la posición de los interruptores.

P1	P2	r/min
0	0	PC
0	1	60
1	1	200
1	0	400

Con este sencillo control podemos variar la velocidad de nuestro motor sin necesidad de utilizar el ordenador.

Se recomienda iniciar la marcha de los motores con una velocidad de entre 60 r/min y 100 r/min y no reducir esta a menos de 60 r/min, ya que puede bloquearse el motor.

En el programa también aparece un control llamado "*Multiplicar Incremento*", con un valor por defecto de 5. Si variamos este parámetro podemos conseguir que el bloque variador de frecuencia aumente o disminuya la velocidad más rápidamente o menos. Conviene no tocarle, pues si la variación de velocidad se produce muy rápido, el motor se puede bloquear.