MC4X15A

Universal Motor Controller

Revision 1.0 / 14.May.2017

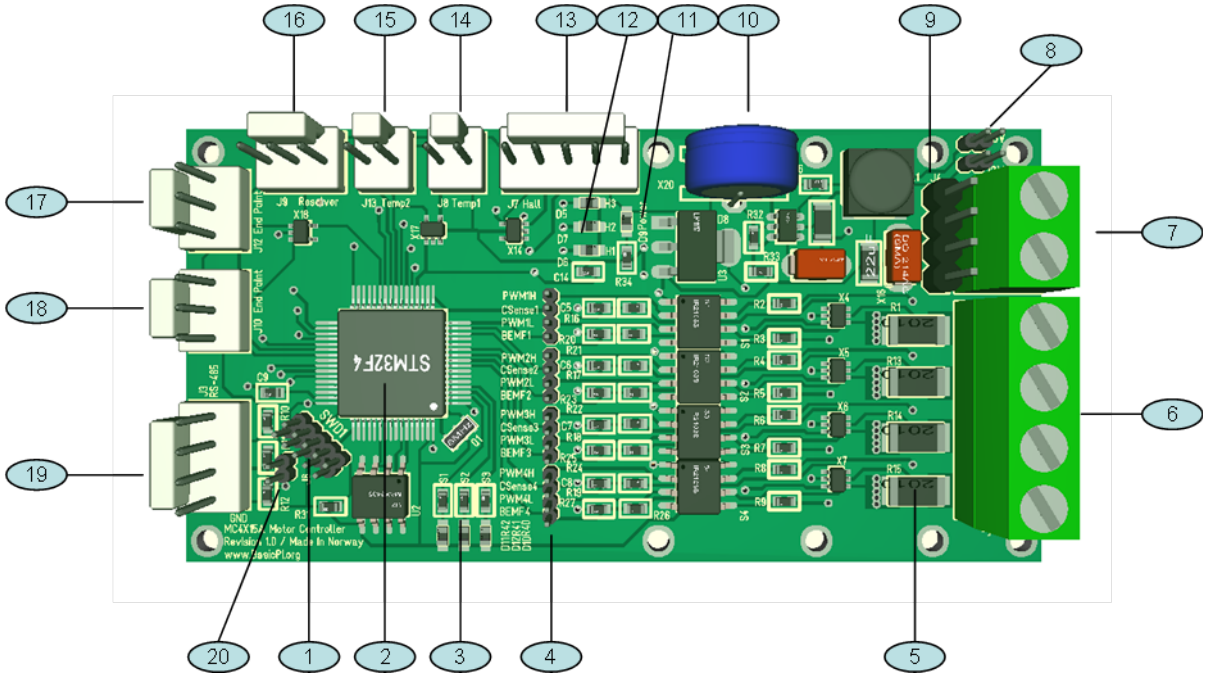
MC4X15A is a Motor Controller based on 4 separate half-bridge drivers capable of driving 12-24V @ 15A each. Peak current can be larger. The controller is equipped with a powerfully STM32 M4, RS485, temp sensors, end stops, resolver, hall sensors, current sensors and voltage/bemf sensors to support a wide variety of applications.

- Solenoid Driver
- DC Motor Driver
- Stepper Motor Driver
- Brushless 3-Phase Motor Driver

Content

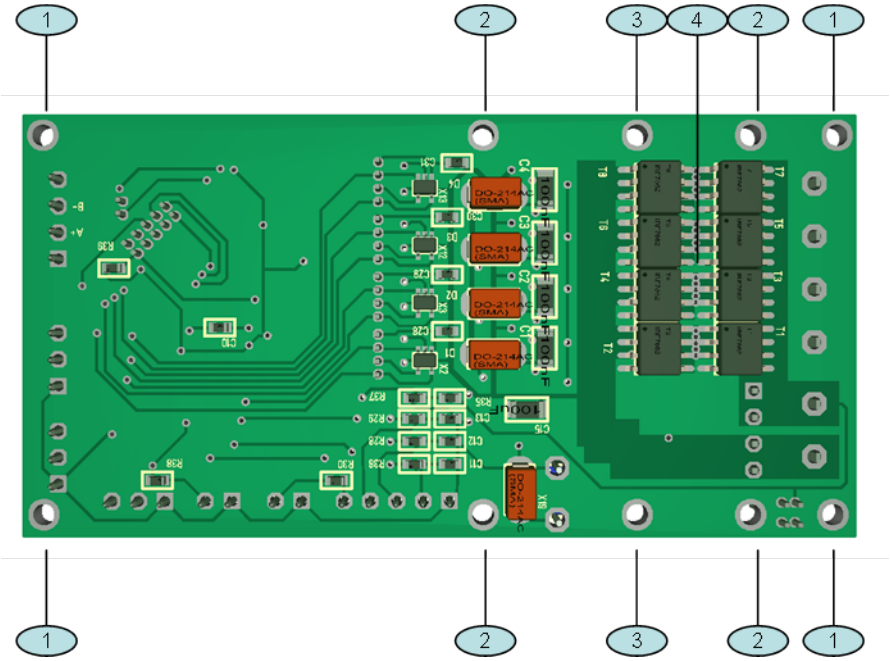
- STM32F405RG, 32-bit ARM M4, 168Mhz RISC MCU
- 1Mb Flash, 192Kb SRAM
- SWD Adapter
- 3 status led’s.
- 4 separate half-bridge drivers supporting 12-24V @15A each. All with current sensors and BEMF sensors.
- High Speed RS-X/RS485
- Hall sensors with separate leds.
- Input Voltage Sensor.
- 2 x Temperature sensors.
- 2 x End Stops
- 1 x Resolver input.
- Separate 3.3V «stay-alive» supercap.
- Adapter for battery or capacitors.
- Size 80 x 40mm. Height depending on adapter board.

MC4X15A Top Side Annotation



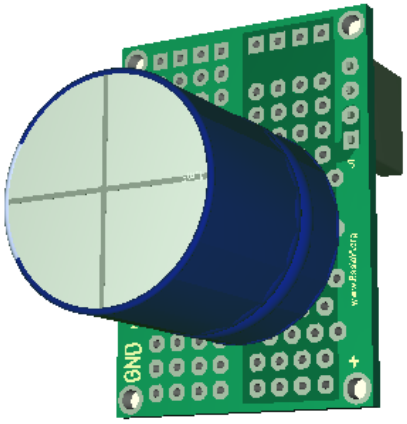
#	Description
1	BasicPI SWD connector with SWD, Reset, Boot 3.3V & UART.
2	STM32F405RG. 32 bit ARM MCU w/1MbFlash, 192KbSRAM and M4 floating point support. Can be replaced with STM32F105RB.
3	Status leds.
4	Test points or external connection to all BEMF, Current and PWM signals.
5	Current shunts.
6	4 x Half Bridge PWM output.
7	Power Input 12-24V
8	1.27 pitch Jumper for 12V/24V Input
9	2.54 pitch power adapter for battery, capacitor and break resistors.
10	3.3V Super capacitor.
11	Power Led.
12	Hall Sensor Leds.
13	Hall Sensor Connector.
14	Temperature Sensor Connector. Shown on top here, but can be mounted inwards on the back for sensors between the HEXFET’s.
15	Temperature Sensor 2.
16	Resolver input. Basically an analogue pin with 6V suppression diode.
17	End point connector.
18	End point connector.
19	RS-485 Connector
20	Terminal jumper for RS-485.

MC4X15A Back Side Annotation



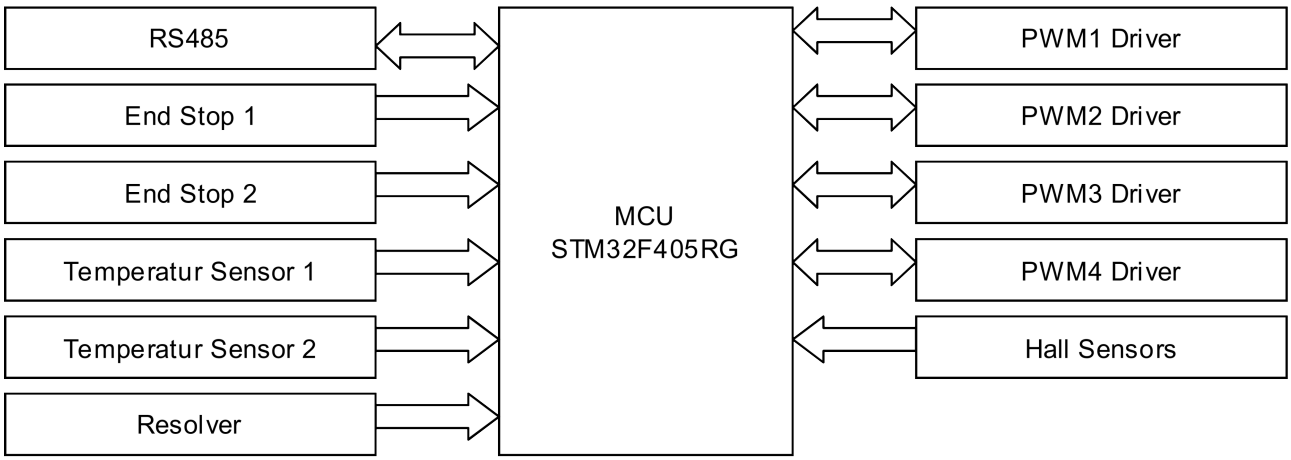
#	Description
1	4 xM2 Mounting holes for external mounting.
2	4 x M2 mounting holes for Battery/Capacitor adapter board.
3	2 extra M2 Mounting holes for heatsink. Must share 2 mounting holes with the adapter board.
4	8 x HEXFET’s mounted on the back with M2 screw holes to fit small heatsink.

Capacitor Adapter Board



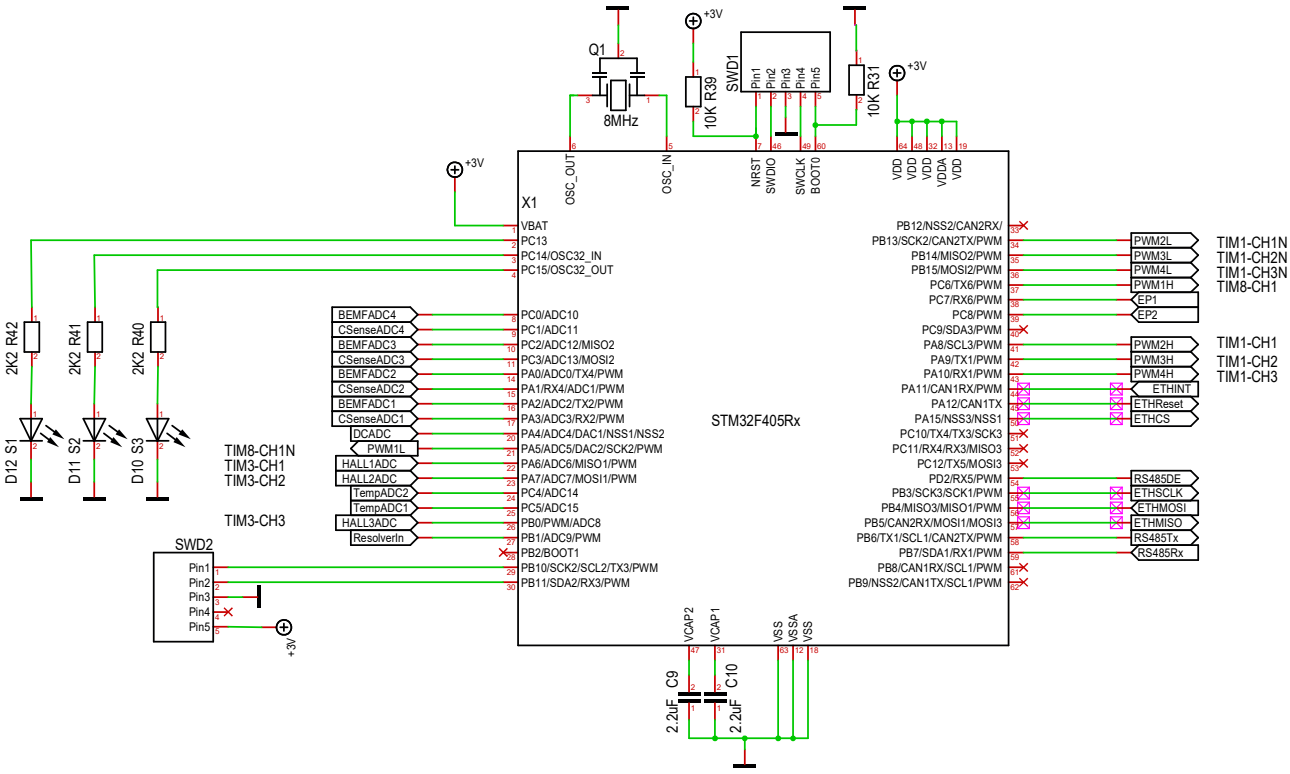
The Capacitor Adapter Board is basically a specialized vero board designed to add hole through capacitors as needed. This needs to be adapted to the motor in use.

Functional Block Diagram



Schematics

MCU



The schematics above show the MCU itself. An 8Mhz Murata ceramic x-tal, SWD connector and 3 x LED’s. The MCU connection points are listed in the table below.

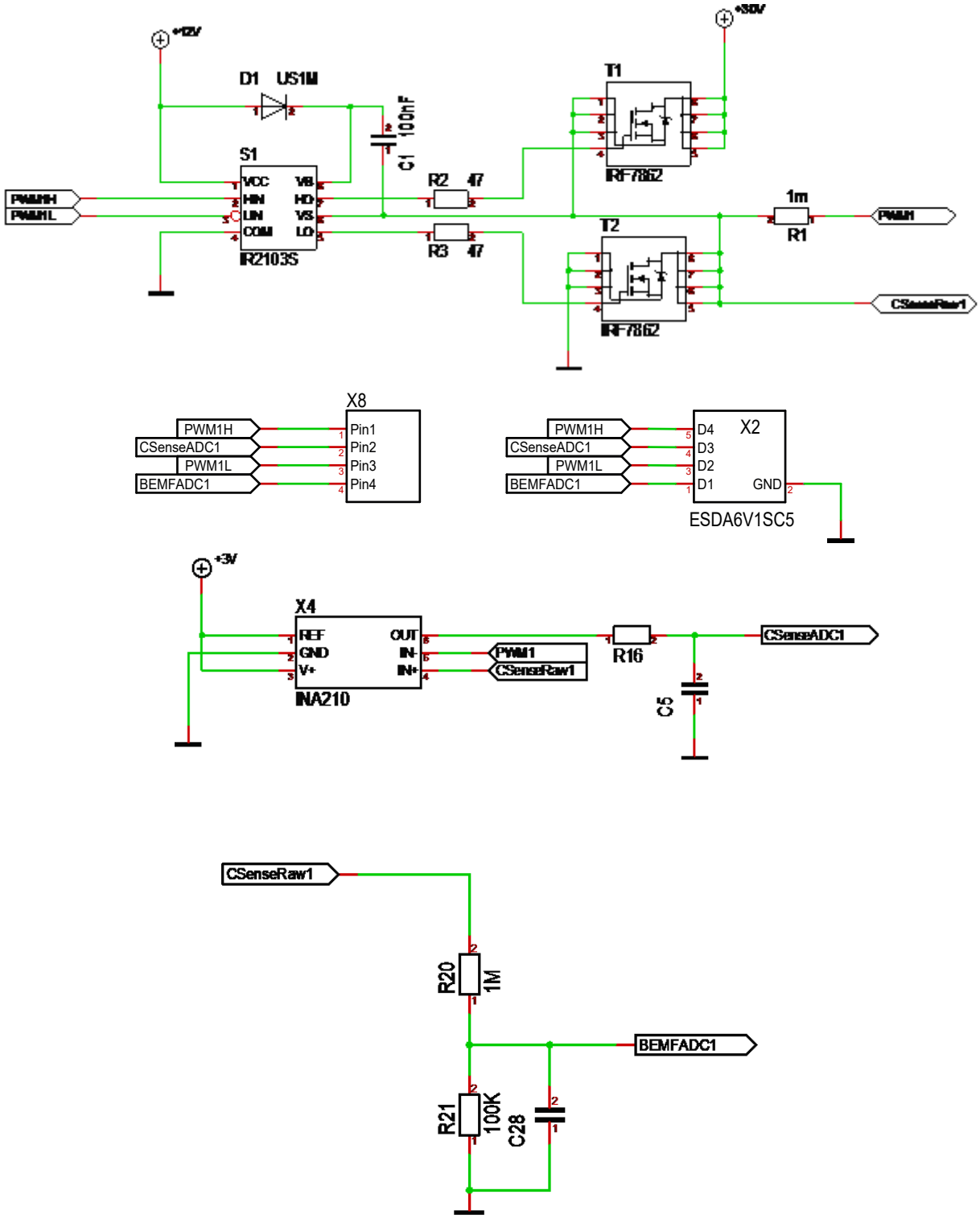
X-Tal	Pin 5 & 6	Ceramic Murata with a small all-in-one 3mm package is used to save space. Using a ceramic crystal is much better than the internal RF crystal, but not as accurate as a proper crystal.
VCAP	Pin 31 & 47 connected to a 2.2uF capacitor.	This must be replaced with 0Ohm resistors for STM32F105Rx.
SWD	7 NRST	
	48 SWDIO	
	49 SWCLK	
	60 BOOT0	
	29 TX3	
	30 RX3	
PWM w/Sensors	37 PWM1H	PC6 TIM8-CH1
	21 PWM1L	PA5 TIM8-CH1N
	16 BEMFADC1	PA2 - ADC2
	17 CSenseADC1	PA3 - ADC3
PWM2 w/Sensors	41 PWM2H	PA8 - TIM1-CH1

	34 PWM2L	PB13 - TIM1-CH1N

	14 BEMFADC2	PA0 - ADC0
	15 CSenseADC2	PA1 - ADC1
PWM3 w/Sensors	42 PWM3H	PA9 – TIM1-CH2
	35 PWM3L	PB14 – TIM1-CH2N
	10 BEMFADC3	PC2 - ADC12
	11 CSenseADC3	PC3 - ADC13
PWM4 w/Sensors	43 PWM4H	PA10 - TIM1-CH3
	36 PWM4L	PB15 - TIM1-CH3N
	8 BEMFADC4	PC0 - ADC10
	9 CSenseADC4	PC1 - ADC11
HALL Sensors	22 HALL1ADC	PA6 – TIM3 – CH1 / ADC6
	23 HALL2ADC	PA7 – TIM3 – CH2 / ADC7
	26 HALL3ADC	PB0 – TIM3 – CH3 / ADC8
Voltage In Sensor	20 DCADC	PA4 - ADC4
Resolver	27 ResolverIn	PB1 – ADC9 / PWM
Temperature 1	25 TempADC1	PC5 - ADC15
Temperature 2	24 TempADC2	PC4 - ADC14
End point 1	38 EP1	PC7
End point 2	39 EP2	PC8
Ethernet	44 ETHINT	PA11
	45 ETHReset	PA12
	50 ETHCS	PA15
	55 ETHSCLK	PB3 SPI1 or 3
	56 ETHMOSI	PB4 SPI1 or 3
	57 ETHMISO	PB5 SPI1 or 3
RS-485	54 RS485DE	PD2
	58 RS485Tx	PB6 TX1
	59 RS385Rx	PB7 RX1
Spare SPI	51 SCK3	PC10
	52 MISO3	PC11
	53 MOSI3	PC12
Spare CAN	61 CAN1RX	PB8
	62 CAN1TX	PB9
Spare	33 PB12	
	40 PC9	
	28 PB2	

PWM Driver 1

This show the schematics for PWM1 and associated current sensor, BEMF Sensors, connectors and protection logic.



PWM Driver 1,2,3 & 4 are identical, so only PWM Driver 1 is annotated here.

The Gate Driver shown are IR2103S, but the actual circuit will be using IR2101S. IR2101,IR2102 & IR2103 are pin compatible and identical with exception of input logic. IR2101 is better suited for

connection to a modern PWM driver, while IR2103 can use a combined input line as it invert the LIN.

T1 & T2 are IRF7862 rated at 30V, 21A. These are HEXFET's in SO8 packages that have a large range of pin-compatible alternatives.

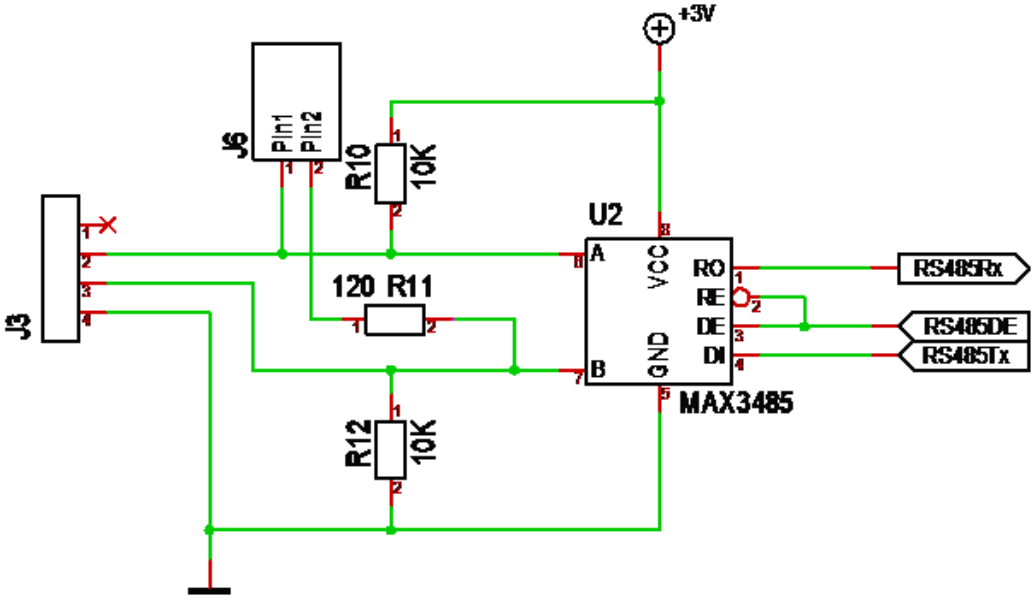
R1 is the 0.001 currents shunt that is measured by the zero-drift current sensor INA210. R16 & C5 form a low-pass filter to remove as much noise as possible. INA210 is pin compatible with a range of sensors using different amplifications.

R20, R21 & C28 is a current splitter & low pass filter for BEMF sensing.

X8 is the 1.27 pitch connector making signals available for scopes etc.

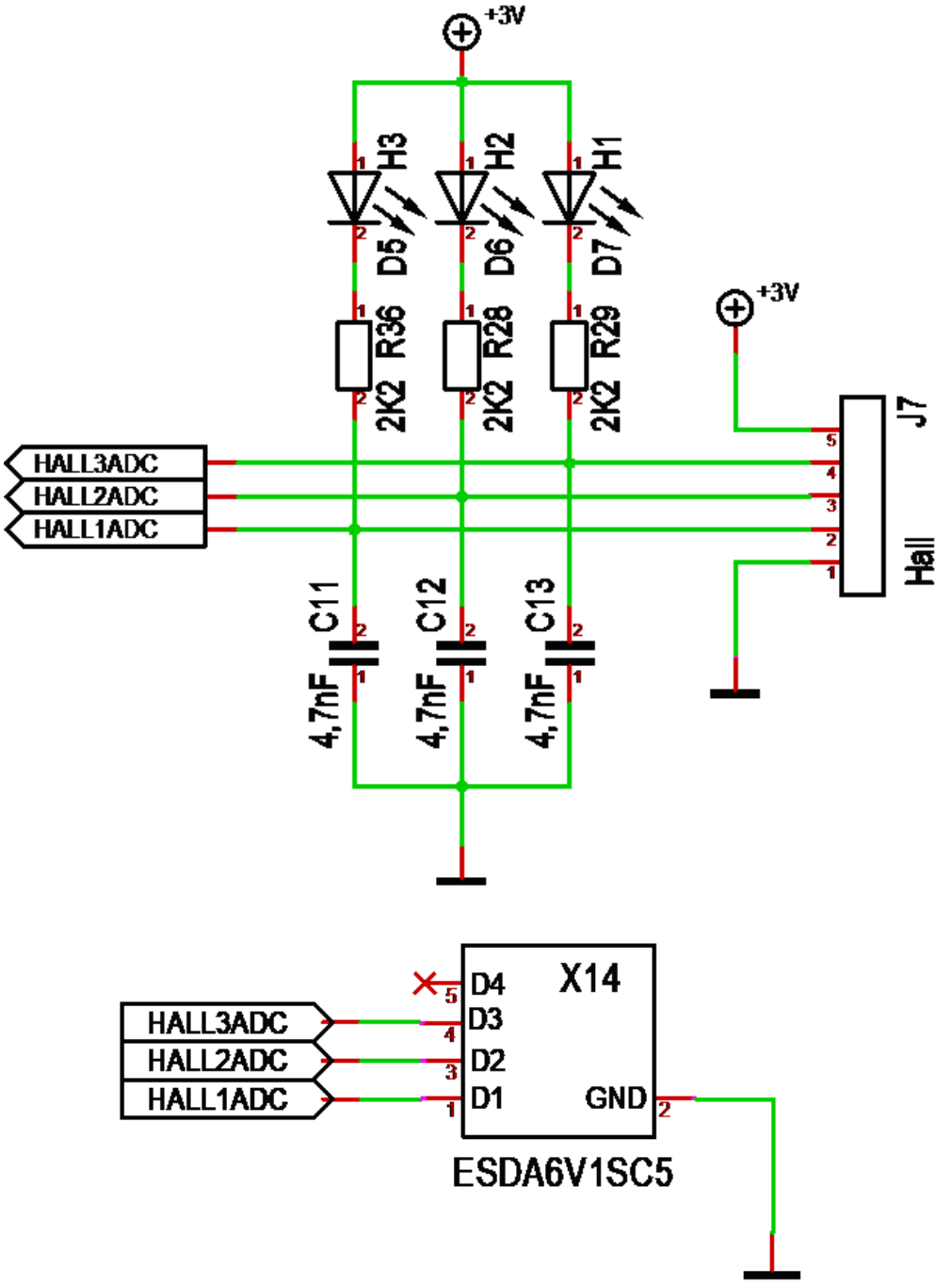
X2 is a 6.1V suppression diode used on all signals connected to the MCU for protection.

RS485



Classic RS485 transceiver based on MAX3485. This is a 3.3V version of the more known MAX485.

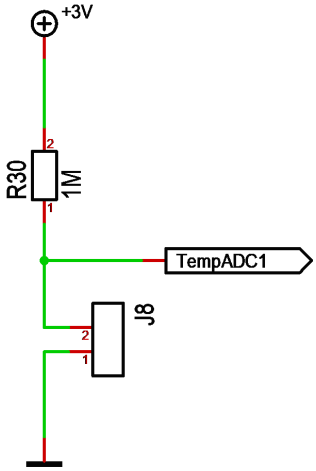
Hall Sensors



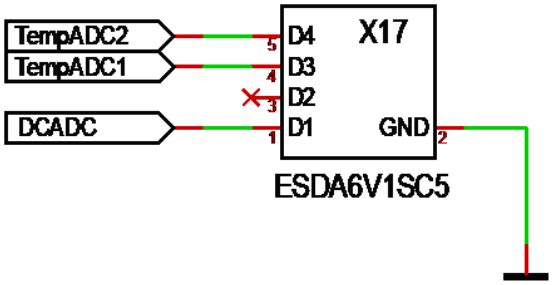
Hall sensors have a separate connector that provided 3.3V & GND out and 3 x Hall Sensor’s in. The Led’s will light up as the sensor input’s are low. The capacitors and suppression diodes should prevent pulses.

Hall sensors are connected to Timer 3, channel 1,2 &3 where they can be counted directly by the timer logic.

Temperature Sensor

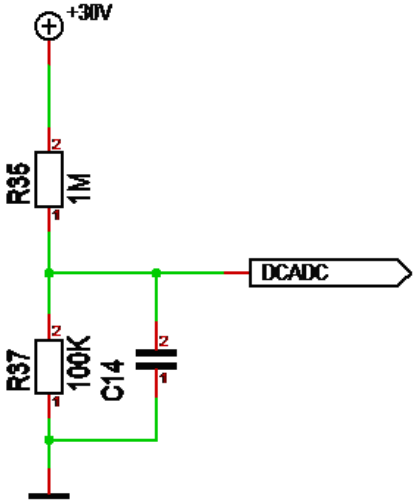


Temperature Sensor 1 & 2 are identical, only #1 is annotated here. This is a basic current splitter with the temperature sensor as the 2nd, variable resistor. The intention is that one (or both) sensors are located between the HEXFET's and the heatsink.



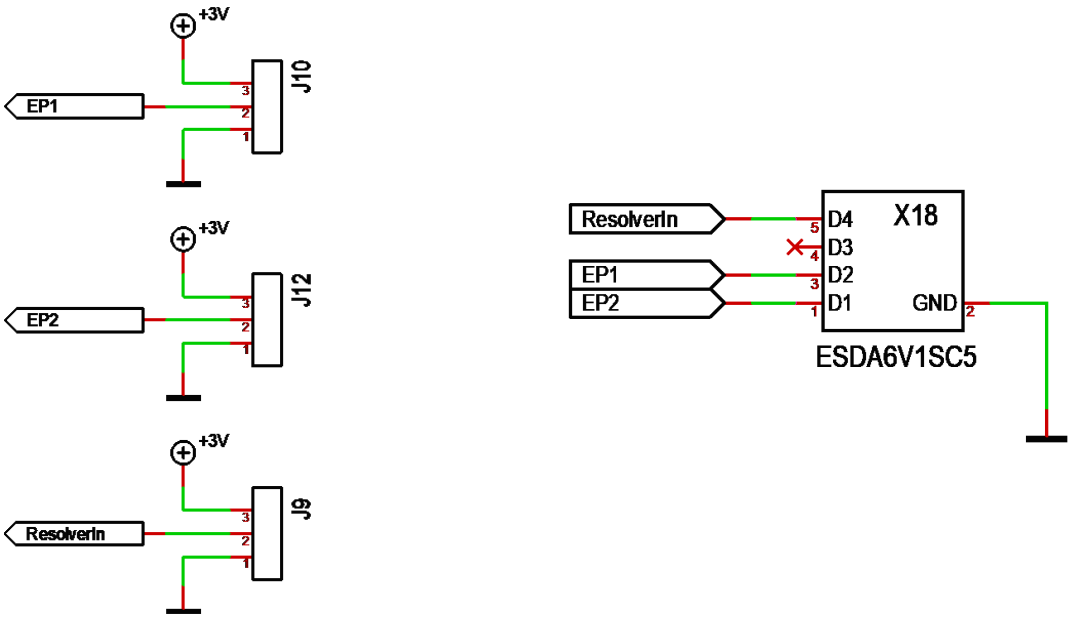
This illustrate the suppression diodes for Temperature sensor 1,2 and DC Voltage Sensor.

DC Voltage Sensor's



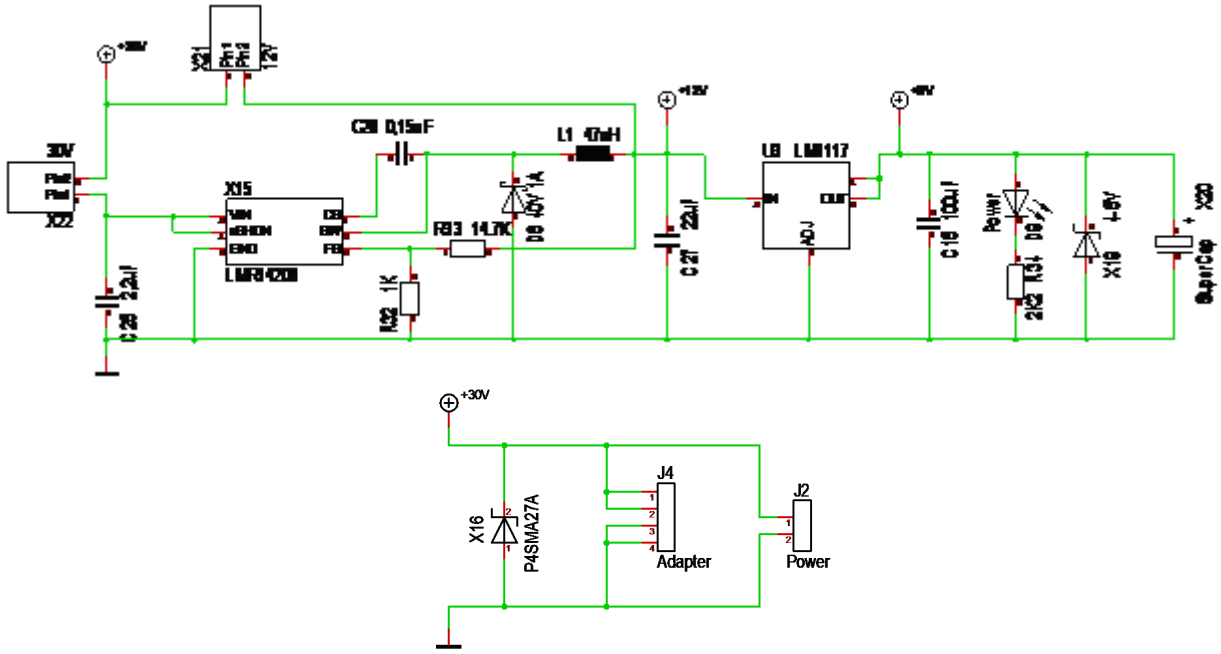
DC Voltage Sensor is a classic voltage splitter with a low pass filter and suppression diode connected to an ADC. By design this should drop several seconds before the 3.3V to the MCU drops out due to the supercap on the 3.3V PSU. This gives us the capability to monitor power drops that otherwise would reboot the MCU.

End Point & Resolver



Endpoint1, Endpoint2 and Resolver uses the same design with a connector consisting of the signal, 3.3V and GND. The only added logic is the suppression diode.

PSU



The PSU provides 3 voltages. (1) is the raw input voltage used on the motor. This must be 12-24V. (2) is the 12V used on the Gate Driver logic provided either by direct input or by using the DC-DC converter. (3) is a 3.3V PSU provided by a classic LM1117.

A supercap on the 3.3V (roght top) will function as a battery and keep the MCU alive a few seconds after a power drop. The adapter (bottom) allows an external battery, capacitor or break resistor to be connected.

Jumpers are added to support input voltages as low as 11.1V from LIPO batteries. The circuit can support 30V if you replace the X16 suppression diode that otherwise will activate at ca 27V.

BOM

C1	100nF	PWM1 page 2	
C10	VCAP 2.2uF	MCU page 1	
C11	4.7nF	Page 4	
C12	4.7nF	Page 4	
C13	4.7nF	Page 4	
C14	2.2nF	Page 4	
C15	100uF	Page 5	
C2	100nF	PWM2 page 2	
C26	0,15uF	Page 5	
C27	22uF	Page 5	
C28	2.2nF	Page 4	
C29	2.2nF	Page 4	
C3	100nF	PWM3 page 2	
C30	2.2nF	Page 4	
C31	2.2nF	Page 4	
C4	100nF	PWM4 page 2	
C5	2.2nF	Page 4	
C6	2.2nF	Page 4	
C7	2.2nF	Page 4	
C8	2.2nF	Page 4	
C9	VCAP 2.2uF	MCU page 1	
D1	US1M	PWM1 page 2	
D10	Led	MCU page 1	
D11	Led	MCU page 1	
D12	Led	MCU page 1	
D2	US1M	PWM2 page 2	
D3	US1M	PWM3 page 2	
D4	US1M	PWM4 page 2	
D5	Hall sensor Led	Page 4	
D6	Hall sensor Led	Page 4	
D7	Hall sensor Led	Page 4	
D8	40V 1A TVS Diode	Page 5	
D9	Power Led	Page 5	
J1	4 x Motor Screw Connector	Page 2	
J10	3 pin 2.54 pitch connector	Page 4	
J11	3 pin 2.54 pitch connector	Page 4	
J13	2 pin 2.54 pitch connector	Page 4	
J2	2 x Screw comnnector	Page 2	
J3	4 pin 2.54 pitch connector	Page 3	
J4	2.54 pitch male pin header	Page 2	

J6	1.27 pitch jumper	Page 3	
J7	5 pin 2.54 pitch connector	Page 4	
J8	2 pin 2.54 pitch connector	Page 4	
J9	3 pin 2.54 pitch connector	Page 4	
L1	47uH 1A	Page 5	
Q1	8 Mhz Murata x-tal	MCU page 1	
R1	1mOhm Shunt Resistor	PWM1 page 2	
R10	10K bias	Page 3	
R11	120 Ohm Terminator	Page 3	
R12	10K bias	Page 3	
R13	1mOhm Shunt Resistor	PWM2 page 2	
R14	1mOhm Shunt Resistor	PWM3 page 2	
R15	1mOhm Shunt Resistor	PWM4 page 2	
R16	10K	Page 4	
R17	10K	Page 4	
R18	10K	Page 4	
R19	10K	Page 4	
R2	47	PWM1 page 2	
R20	1M	Page 4	
R21	100K	Page 4	
R22	1M	Page 4	
R23	100K	Page 4	
R24	1M	Page 4	
R25	100K	Page 4	
R26	1M	Page 4	
R27	100K	Page 4	
R28	2.2K Led Resistor	Page 4	
R29	2.2K Led Resistor	Page 4	
R3	47	PWM1 page 2	
R30	1M	Page 4	
R31	10K Pull-Down	MCU page 1	
R32	1K	Page 5	
R33	14,7K	Page 5	
R34	2.2K Led Resistor	Page 5	
R35	1M	Page 4	
R36	2.2K Led Resistor	Page 4	
R37	100K	Page 4	
R38	1M	Page 4	
R39	10K Pull-Up	MCU page 1	
R4	47	PWM2 page 2	
R40	2.2K Led resistor	MCU page 1	
R41	2.2K Led resistor	MCU page 1	

R42	2.2K Led resistor	MCU page 1	
R5	47	PWM2 page 2	
R6	47	PWM3 page 2	
R7	47	PWM3 page 2	
R8	47	PWM4 page 2	
R9	47	PWM4 page 2	
S1	IR2103S	PWM1 page 2	
S2	IR2103S	PWM2 page 2	
S3	IR2103S	PWM3 page 2	
S4	IR2103S	PWM4 page 2	
SWD1	1.27 pitch Connector	MCU page 1	
SWD2	1.27 pitch Connector	MCU page 1	
T1	IRF7862	PWM1 page 2	
T2	IRF7862	PWM1 page 2	
T3	IRF7862	PWM2 page 2	
T4	IRF7862	PWM2 page 2	
T5	IRF7862	PWM3 page 2	
T6	IRF7862	PWM3 page 2	
T7	IRF7862	PWM4 page 2	
T8	IRF7862	PWM4 page 2	
U1	STM32F405RG	MCU page 1	
U2	MAX3485	Page 3	
U3	LM1117	Page 5	
X10	1.27 pitch Male Header	Page 2	
X11	1.27 pitch Male Header	Page 2	
X12	ESDA6V1SC5	Page 2	
X13	ESDA6V1SC5	Page 2	
X14	ESDA6V1SC5	Page 4	
X15	LMR14206	Page 5	
X16	P4SMA27A	Page 2	27V Suppression diode
X17	ESDA6V1SC5	Page 4	
X18	ESDA6V1SC5	Page 4	
X19	4+ V Suppression Diode	Page 5	
X2	ESDA6V1SC5	Page 2	
X20	Supercap	Page 5	
X21	12V 1.27 pitch Jumper	Page 5	
X22	30V 1.27 pitch Jumper	Page 5	
X3	ESDA6V1SC5	Page 2	
X4	INA210	Page 4	
X5	INA210	Page 4	
X6	INA210	Page 4	
X7	INA210	Page 4	

X8	1.27 pitch Male Header	Page 2	
X9	1.27 pitch Male Header	Page 2	