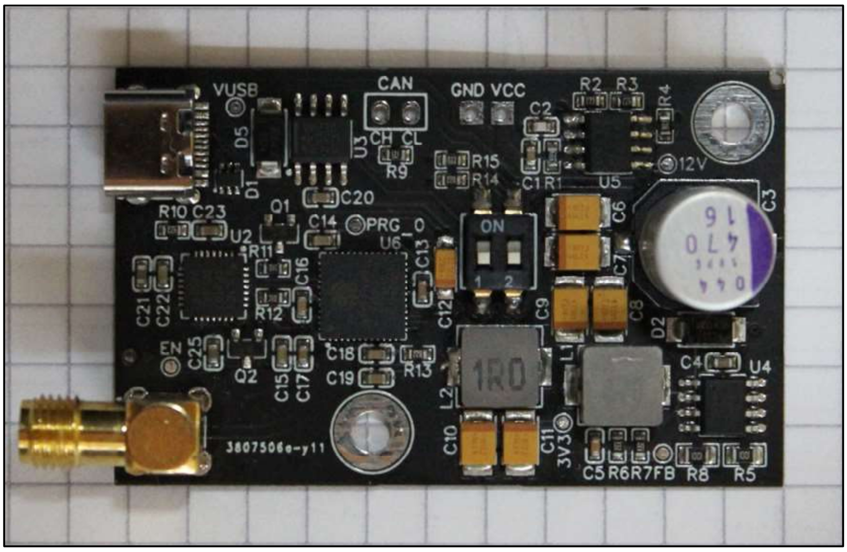
Documentation – Telemetry V2

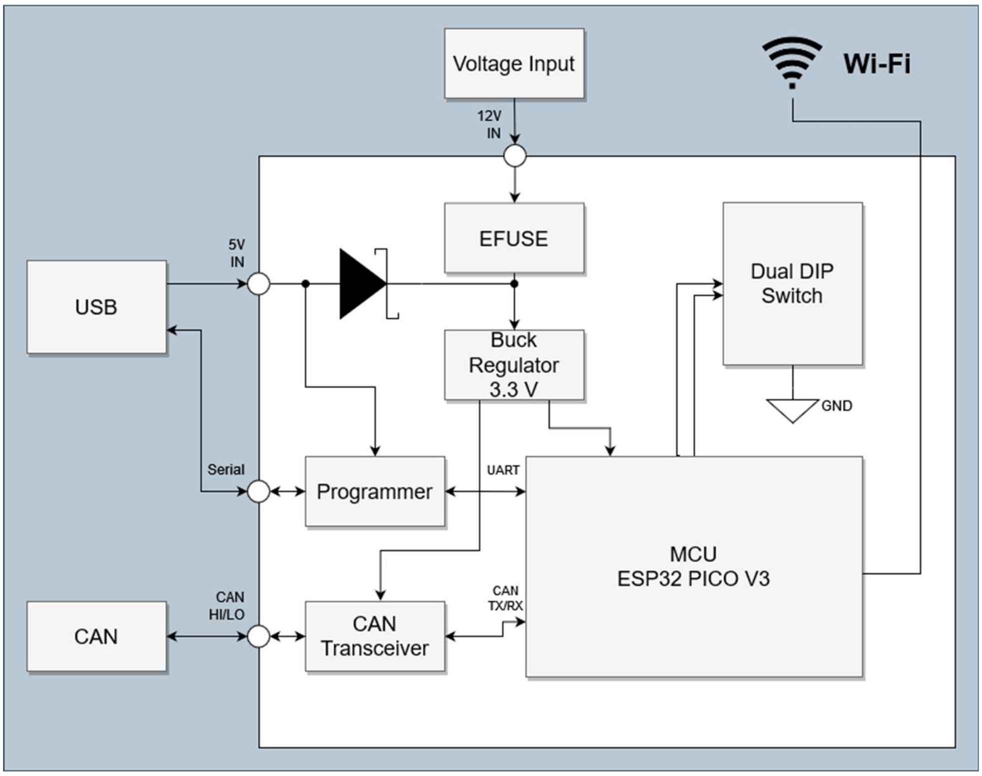


1 Introduction

The Telemetry Unit is a circuit based on the Shifting Unit. It incorporates an ESP 32 microcontroller with an on-board USB programmer and a CAN interface. Unlike the shifting unit, this board also provides a standard SMA connector for an external Wi-Fi antenna and two DIP switches which can connect ESP 32 inputs to ground over an 8.2 kilo ohm resistor. An EFUSE protects the 3.3 V power rail.

2 Contents

3 Block Diagram



4 Specifications

Parameter	Notes	Min.	Typ.	Max.
U_{in}	-	6.4 V	12 V	14.86 V
I_{in}	-	-	170 mA	860 mA
I_{stby}	U_{in} = 12 V	-	15 mA	-
U_{3V3} ripple	I_{3V3} = 0 I_{3V3} = 500 mA	- -	- -	12 mVpp 24 mVpp

5 Block Descriptions

5.1 EFUSE

The EFUSE used is the ***TPS25921ADR*** by Texas Instruments. It offers overvoltage protection (OVP), undervoltage protection (UVP), overcurrent protection (OCP), short circuit protection (SCP) and an adjustable slew rate start-up.

The $R_{ds(on)}$ value is 90 mΩ (typ.), which at 170 mA (the expected current load, calculated with the expectation of 500 mA being drawn by the MCU) constitutes a loss of just 2 mW. Should the output reach the maximum set by overcurrent protection (860 mA), the power dissipated will still be only 67 mW.

5.1.1 OVP and UVP

Over- and under voltage protection is set by a combination of the R_1, R_2 and R_3 resistors. The following equations (which correspond to a voltage divider) describe the relationship:

$$U_{OVPR} = \frac{R_3}{R_1 + R_2 + R_3} \times U_{OVP}$$

$$U_{ENR} = \frac{R_2 + R_3}{R_1 + R_2 + R_3} \times U_{UVP}$$

where $U_{OVPR} = U_{ENR} = 1.4$ V. The values selected using these equations are $R_1 = 390$ kΩ, $R_2 = 62$ kΩ and $R_3 = 47$ kΩ, which sets U_{OVP} at 14.86 V and U_{UVP} at 6.41 V.

The resistors used for this should be relatively accurate. The prototype board uses ±1% tolerance resistors with a temperature drift of 100 ppm/°C. This means that at ambient temperature, U_{OVP} should range between 14.59 V and 15.14 V and U_{UVP} should range between 6.31 V and 6.51 V, however, these are worst case values with resistors at the lower and upper bounds of their tolerance. In practice, the differences in resistor values should offset each other and the set value should prove relatively accurate.

5.1.2 OCP

The resistor R_4 sets the overcurrent threshold, and its value can be determined using the equation (note: current in amperes and resistance in kilo ohms):

$$R_4 = \frac{I_{lim} + 0.018}{10.73 \times 10^{-3}}$$

R_4 was chosen as 82 kΩ, which sets the limit at 860 mA. Accounting for the 1% tolerance of the selected resistor; this value should be between 817 mA and 889 mA.

5.1.3 SCP

Short circuit protection acts as a faster alternative to OCP and is set by the same resistor, R_4. According to the following equation:

$$I_{fasttrip} = 1.42 \times 10^{-2} \times R_4 + 0.36$$

the short circuit protection will be activated should the output current reach 1.52 A.

According to measurements of the prototype board, a short circuit on the 3.3 V rail will lead to disconnection of power in less than 1 ms.

5.1.4 Slew-Rate Controlled Startup

The output slew-rate is set using the C_2 capacitor. Its value was kept quite low at 100 pF. The following equation describes the ramp time:

$$t = 20.6 \times 10^4 \times U_{in} \times (C_2 + 70 \times 10^{-1}\ )$$

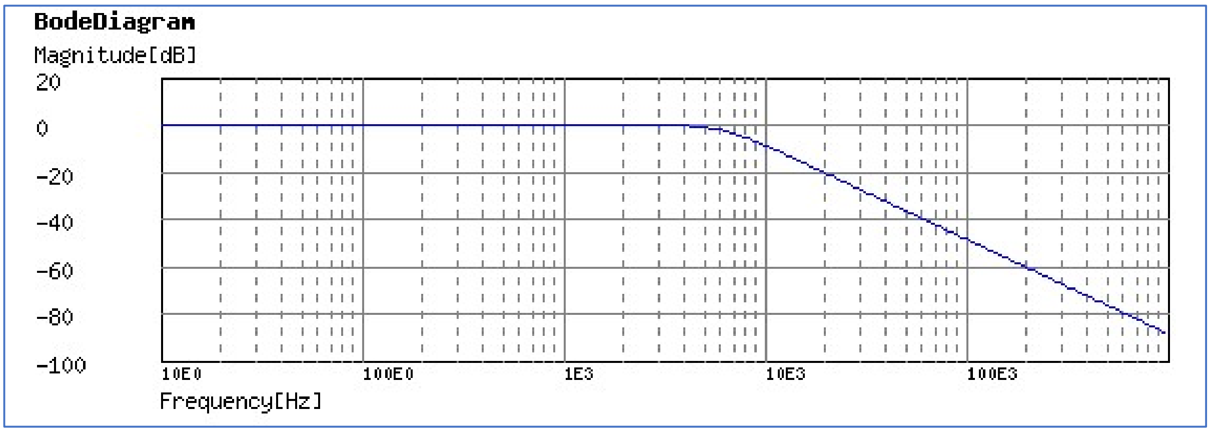
With a voltage input of 12V, the calculated time is around 420 µs. This value should be carefully considered, as during controlled startup, the EFUSE acts as a linear regulator, therefore a considerable amount of power is dissipated as heat.

5.2 Buck Regulator

The regulator selected is the ***XL1509-ADJE1***. It requires a minimum forward voltage of 1.2 to 1.4 V. As it is adjusted to output 3.3 V, it's input voltage should be at least 4.7 V.

Its **maximum output current** is 2 A, which corresponds to around 740 mA of current drawn from a 12 V input at the expected 75 % efficiency. This corresponds to 2.2 W of dissipated power, which is quite high for a SOP8L package, especially given that the junction to ambient thermal resistance is 100 °C/W, though it should be noted that not all of this power will be dissipated within the IC (the coil, for example, will likely account for a significant part of the dissipated power).

Its **switching frequency** is 150 kHz, which is filtered using a (custom) LC filter at the output. The capacitance was selected as 2x 100 uF (for ease of manufacture and better parameters) and the inductance as 3.3 uH (although in practice, a 1 uH inductor was mounted instead, providing around 20 dB less attenuation). Assuming the inductor's DC resistance is 165 mΩ, this gives the following frequency response (around -50 dB at 150 kHz):



The **output voltage** is set using the following equation:

$$U_{OUT} = 1.23 \times \left(1 + \frac{R_2}{R_1}\right)$$

Note that R_1 corresponds to R_8 on the schematic, which has a value of 1 kΩ and R_2 is made up of the parallel combination of R_6 and R_7, these being 3.3 kΩ resistors, making the value of R_2 1.65 kΩ. This gives a voltage od 3.26 V. Given that the resistors used have a 1% tolerance, the expected value should be between 3.22 V and 3.30 V. It should also be noted that the regulator itself seems to have a further 3% inaccuracy between the voltage that is set and the voltage that is present on the output.

Following expectations, the measured output voltage has shown itself to be within 50 mV of the set voltage with little to no drift induced by changing the current drawn from the 3.3 V rail.

5.3 MCU

The microcontroller used is the ***ESP32-PICO-V3***. It was chosen over products in the ATMega family (typically used in Arduinos and other single board microcontrollers) due to its apparently lower cost and higher performance. ST chips were avoided due to their apparent overall higher complexity of implementation and their low availability at the time. From within the ESP32 family, a model which supports TWAI (a CAN equivalent) was required, other differences in parameters were generally unimportant for this task. This specific model was selected for its availability.

For utilising its wireless capabilities, additional 100 nF bypass capacitors were added to every power pin.

5.4 CAN Transceiver

The ***SN65HVD230DR*** by Texas Instruments is specific in its ability to run off a 3.3 V voltage supply as opposed to other more common CAN chips, which typically require 5 V to operate. This is highly beneficial as it removes the need for a separate 5 V supply, reducing complexity and increasing efficiency of the circuit.

It supports the ISO 11898 standard and is capable of a throughput of 1 Mb/s.

5.5 DIP Switches

The DIP switches are connected to pins 13 and 21. They are normally open and connect these pins to ground over an 8.2 kilo ohm resistor when switched. These pins should be pulled up using internal pullup resistors.

5.6 Programmer

The ***CP2102-GMR***, a USB to UART bridge, was chosen as the programmer. This is because multiple online schematics depict it being used with an ESP32, and because it can be powered from 5 V USB directly. The board can be programmed without external power, as the MCU is powered from the 5V USB rail though a Schottky diode and the 3.3 V regulator. This also means that the programmer is not powered during normal operation, further improving circuit efficiency.

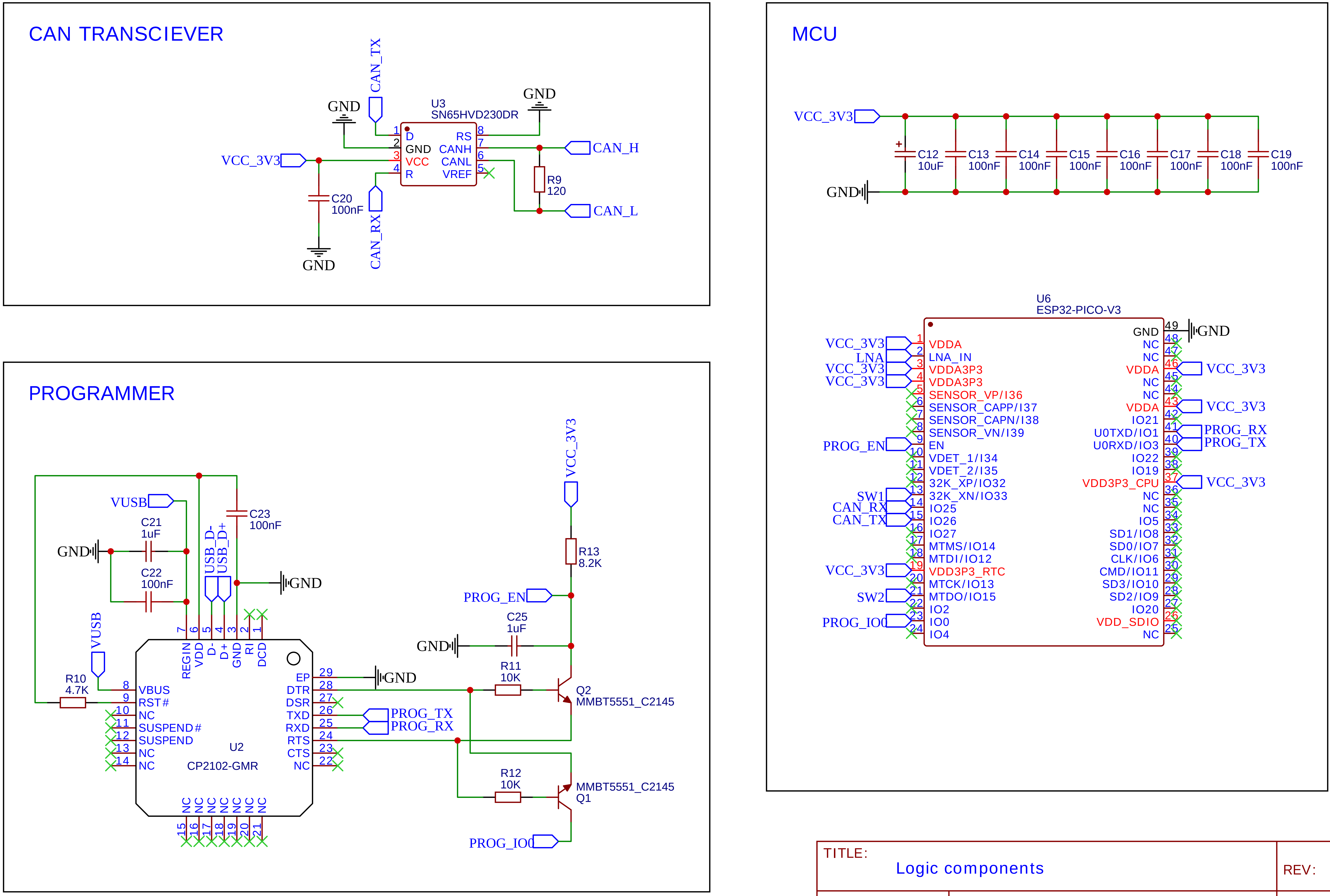
The USB input is protected from voltage spikes, such as those produced by ESD, by the ***SMF05CT1G*** integrated circuit.

6 Test Points

Several test points are provided for troubleshooting the board

- **12 V** – The voltage on this point should be almost identical to battery voltage if connected, and should be around 0.3 V to 0.4 V smaller than **VUSB** if only USB power is connected.
    - If this voltage is not present when USB is connected, diode D5 should be verified.
    - If it is not present or is very low when battery voltage is present, the EFUSE circuit should be verified. The 3.3V rail and regulator input should also be checked for short circuits.

- **FB** – Voltage regulator reference voltage. This value should be 1.23 V.
  - If this voltage is out of bounds, check for short on 3.3 V rail and check **12 V** test point.
- **3V3**– Regulator output after noise filter. This value should be within 3.22 V and 3.30 V with a 3% accuracy (see 5.2 Buck Regulator).
  - If out of spec, verify there is no short on 3.3 V rail and check the **FB** and **12V** test points.
- **VUSB** – Direct measurement of USB input voltage. When USB is unplugged, this voltage should be 0V or slightly positive (0.1 V…)
  - If not present when USB cable is plugged in, verify USB cable and connection.
  - If over 6.5 V, verify diode D5 and subsequently that the programmer, MCU and/or the SMF05CT1G ESD protection circuit are undamaged.
- **EN** and **PROG_0** – These correspond to the IO0 and enable pins on the MCU and are used for programming the MCU. For expected logical values, see ESP32 documentation.



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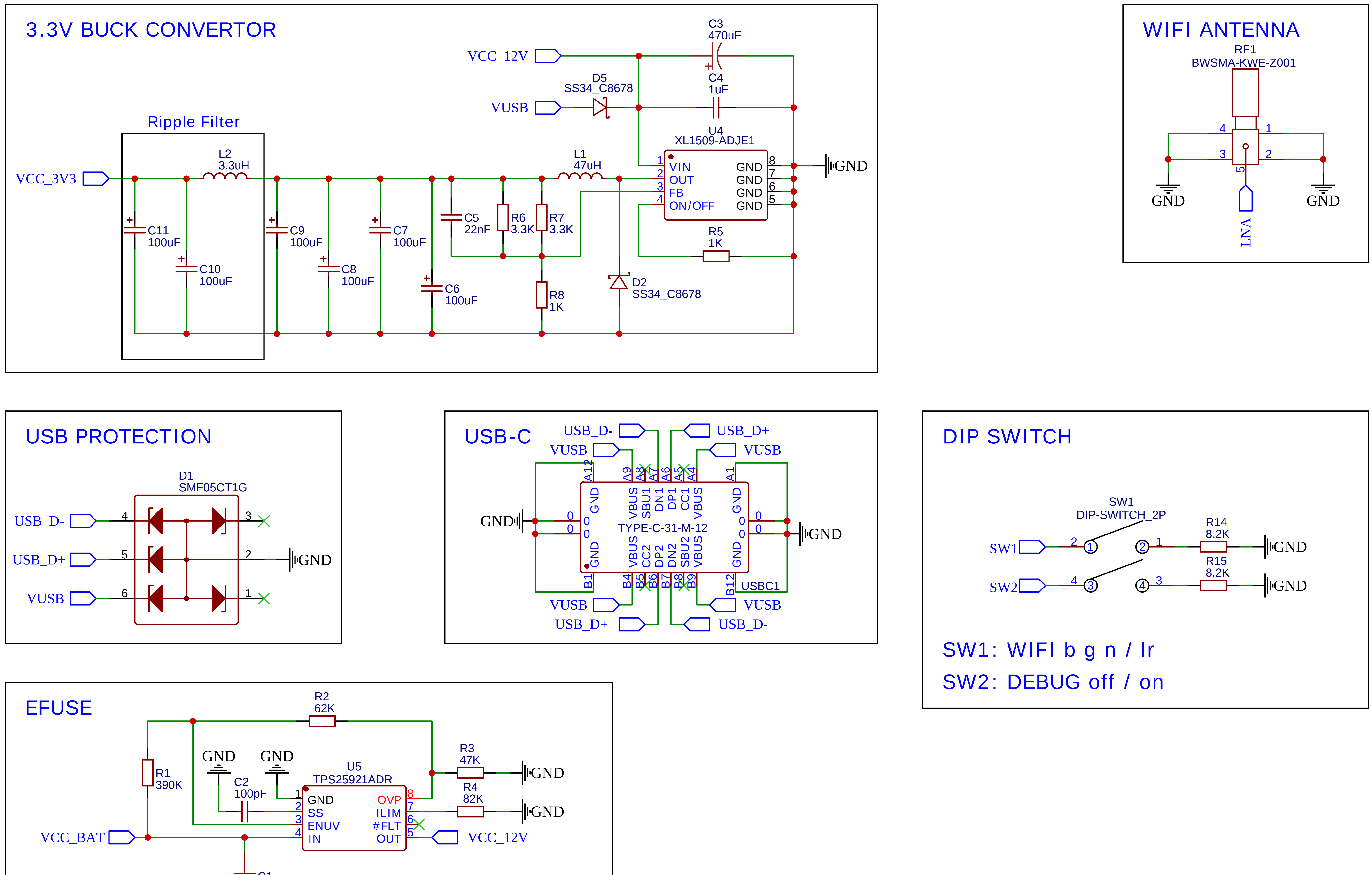
Date: 2021-12-14 Drawn By: V í tek Hanzl í k	

EasyEDA



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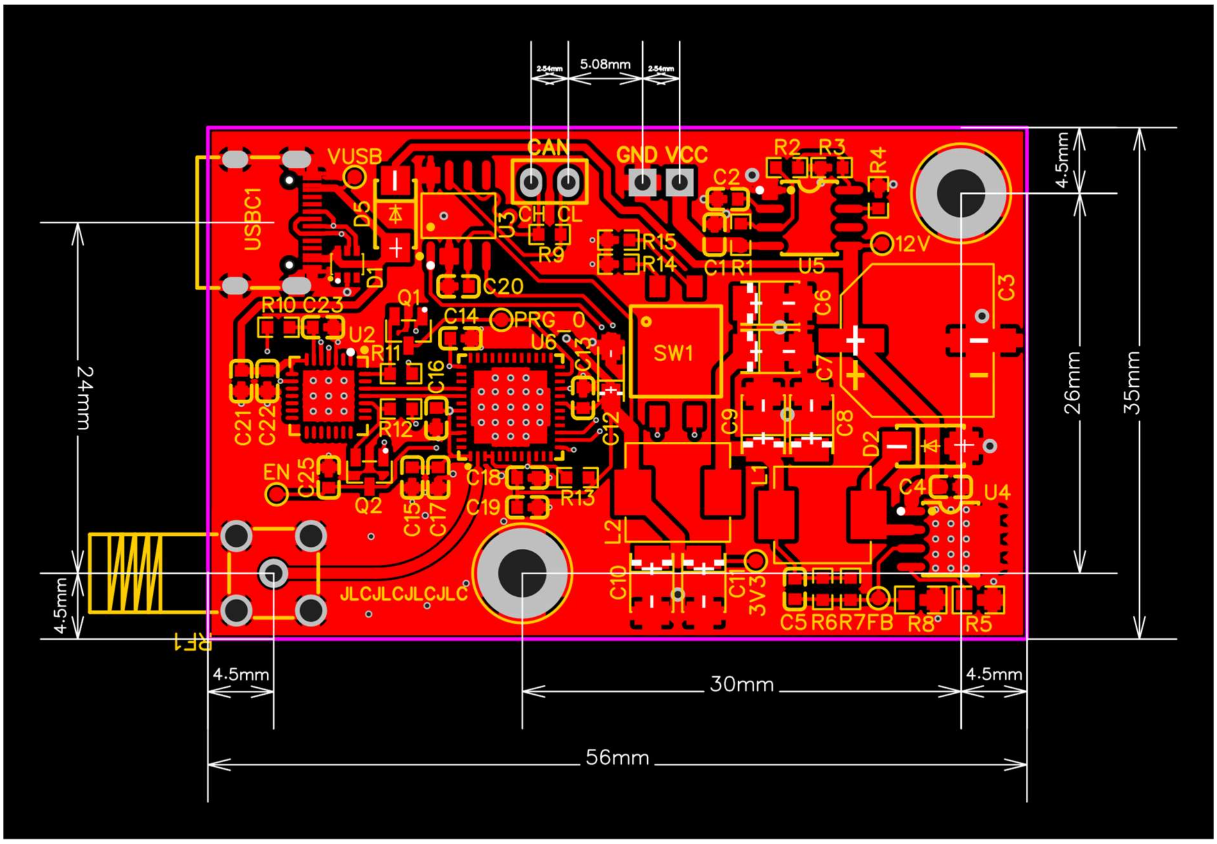
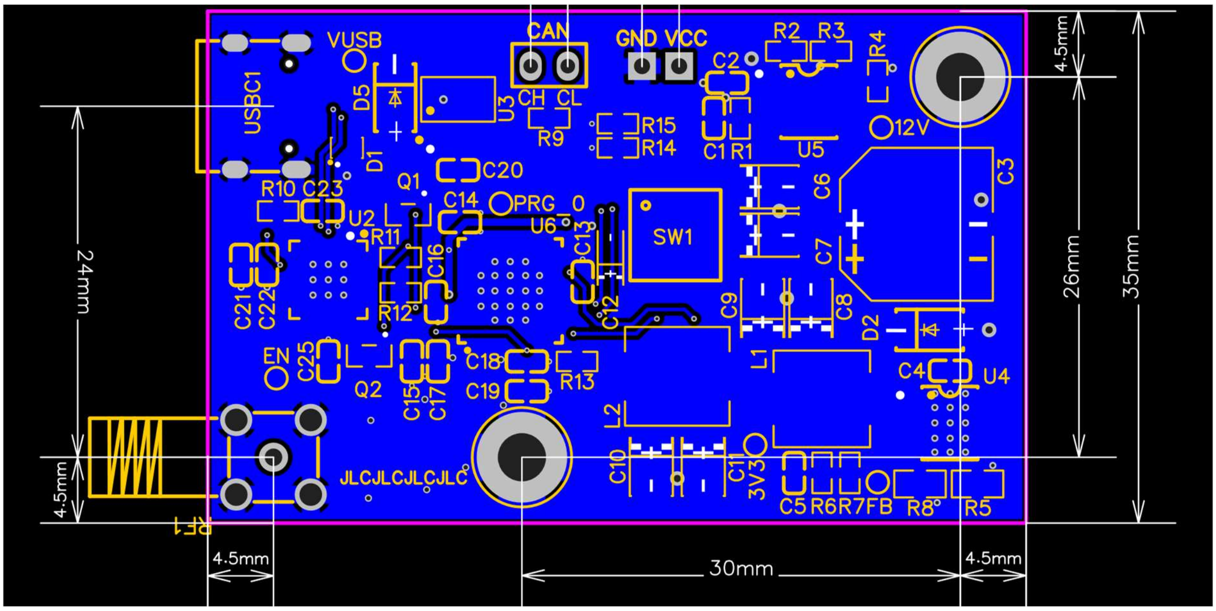
8 PCB


2.54mm
5.08mm
2.54mm
4.5mm
26mm
35mm
24mm
4.5mm
4.5mm
30mm
4.5mm
56mm
VUSB
CAN
GND VCC
USBC1
SW1
JLCJLCJLCJLC
RF1


4.5mm
26mm
35mm
24mm
4.5mm
4.5mm
30mm
4.5mm
VUSB
CAN
GND VCC
USBC1
SW1
JLCJLCJLCJLC
RF1

9 BOM

Name	Designator	Footprint	Qty.	Mfr. Part	Mfr.
BWSMA-KWE-Z001	RF1	SMA-TH_BWSMA-KWE-Z001	1	BWSMA-KWE-Z001	BAT WIRELESS
1uF	C4, C21, C25	C0603	3	CL10A105KB8NNNC	SAMSUNG
8.2K	R13, R14, R15	R0603	3	0603WAF8201T5E	UniOhm
DIP-SWITCH_2P	SW1	DIP_02_SMD	1	ESD102E	DIPTRONICS
100nF	C1, C13, C14, C15, C16, C17, C18, C19, C20, C22, C23	C0603	11	CC0603KRX7R9BB104	YAGEO
100pF	C2	C0603	1	CL10C101JB8NNNC	SAMSUNG
470uF	C3	CAP-SMD_BD10.0-L10.3-W10.3-FD	1	16SVPE470M	PANASONIC
100uF	C10, C11, C6, C7, C8, C9	CAP-SMD_L3.5-W2.8	6	TAJB107K006RNJ	AVX
10uF	C12	CAP-SMD_L3.2-W1.6-R-RD	1	TAJA106K016RNJ	AVX
390K	R1	R0603	1	0603WAF3903T5E	UniOhm
62K	R2	R0603	1	0603WAF6202T5E	UniOhm
47K	R3	R0603	1	0603WAF4702T5E	UniOhm
82K	R4	R0603	1	0603WAF8202T5E	UniOhm
3.3K	R6, R7	R0603_NEW	2	0603WAF3301T5E	UniOhm
1K	R8, R5	R0805	2	0805W8F1001T5E	UniOhm
4.7K	R10	R0603	1	0603WAF4701T5E	UniOhm
10K	R11, R12	R0603	2	0603WAF1002T5E	UniOhm
SS34_C8678	D5, D2	DO-214AC_L4.3-W2.7-LS5.3-RD	2	SS34	MDD
22nF	C5	C0603	1	CL10B223KB8NNNC	SAMSUNG
SMF05CT1G	D1	SOT-363_L2.0-W1.3-P0.65-LS2.1-TL	1	SMF05CT1G	ON
47uH	L1	IND-SMD_L7.1-W6.6	1	SMMS0650-470M	SXN
3.3uH	L2	IND-SMD_L7.3-W6.6_MHCI06030	1	MHCI06018-1R0M-R8A	Chilisin Elec
MMBT5551_C2145	Q1, Q2	SOT-23-3_L2.9-W1.3-P1.90-LS2.4-BR	2	MMBT5551	CJ
120	R9	R0603	1	0603WAF1200T5E	UniOhm
CP2102-GMR	U2	QFN-28_L5.0-W5.0-P0.50-BL-EP	1	CP2102-GMR	SILICON LABS
SN65HVD230DR	U3	SOIC-8_L4.9-W3.9-P1.27-LS6.0-BL	1	SN65HVD230DR	TI
XL1509-ADJE1	U4	SOIC-8_L5.0-W4.0-P1.27-LS6.0-BL	1	XL1509-ADJE1	XLSEMI
TPS25921ADR	U5	SOIC-8_L5.0-W4.0-P1.27-LS6.0-BL	1	TPS25921ADR	Texas Instruments
ESP32-PICO-V3	U6	LGA-48_L7.0-W7.0-P0.50-BL-EP5.0	1	ESP32-PICO-V3	ESPRESSIF 乐鑫
TYPE-C-31-M-12	USBC1	USB-C_SMD-TYPE-C-31-M-12	1	TYPE-C-31-M-12	Rectangular Connectors - Contacts