4.5V Battery Input (3x Series D-Cell Input)

+4.5V
GND
J2
OQ0232510000G
VBATT
TP1
GND
D1
T5V0S5A-7
D4
B240AE-13
TP4
VIN
GND
D5
B240AE-13
USB_VBUS
D2
T5V0S5A-7
GND
Unidirectional 5V TVS Diode

Buck-Boost 3.3V Regulator - Iout < 1.8A

Buck-Boost Regulator Layout
File: lwqms_power_supply.kicad_sch
VIN
VIN
EN
VOUTC
FBC
GND
R4
560k
C3
4p
C4
47uF
TP5
+3V3
D7
T3V3S5A-7
Unidirectional 3.3V TVS Diode
C1
22uF
R5
100k
GND

Buck-Boost 5V Regulator - Iout < 1.8A

Buck-Boost Regulator Layout1
File: lwqms_power_supply.kicad_sch
VIN
5V_EN
VIN
EN
VOUTC
FBC
GND
R6
910k
C5
2.4p
TP9
+5V
C2
22uF
R1
100k
R7
100k
C6
47uF
D8
T5V0S5A-7
Unidirectional 5V TVS Diode
GND

A buck-boost regulator was chosen for this design, as it allows for the D-Cell battery supply to operate anywhere along its output voltage curve (awful looking) and still provide a reliable 3.3V output.

Sensor Inputs

J3
CONBNC002
PH_RAW
TP2
PH_GND
GND
D3
T5V0S5A-7
PH Sensor Pre-Amplifier ALT
pH_IN
pH_OUTD
File: phsensorboard_alt.kicad_sch
PH_IN
J5
OQ0332510000G
TP6
+5V
TP8
EXTRA_IN
EXTRA_GND
D10
T5V0S5A-7
GND

Since the pH sensor puts out between -0.5 and +0.5V, we need to pre-emptively add a DC offset to make it single-ended supply compatible (since the switch itself is not tolerant to reverse polarities at its inputs anyways). This configuration attenuates the sensor input to 1/3 its original value, but this is preferable to a non-working setup.

+5V
R8
4.7k
J4
OQ0332510000G
RTD_SEN
NOTE: PT100 RTD only!
TP7
D9
T5V0S5A-7
RTD_GND
GND
J1
OQ0332510000G
TP3
TURB_IN
R2
OR
R3
4.7k
D6
T5V0S5A-7
TURB_GND
GND
NOTE: OR resistor may need to be swapped for a 470R (unclear schematic)
Additional inputs can be added as needed

SENSOR INPUTS/OUTPUTS ARE ALL ENABLED BY THE 5V_EN PIN OF THE REGULATOR!! - NO NEED FOR REDUNDANT IC TO SAVE POWER FOR A COUPLE OF SECONDS WHILE THE SENSORS ARE TURNED ON.

SPI Flash

+3V3
C11
100n
R15
10k
R16
10k
U5
MX25L3233FM2I-08Q
32Mbit
Vcc
HOLD
WP
GND
CS
MISO
MOSI
SCLK
FLASH_CS
SPI_MISOo
SPI_MOSIo
SPI_SCKo
GND

SPI Flash used to store configuration parameters, past data points, and encryption keys. Enables dynamic configuration of all of these things OTA.

Note the RP2350 has a dedicated QSPI flash memory device targeted for storing firmware binaries.

LoRa Modulator

U4
Core1262 HF
LoRa_CS
SPI_SCKo
SPI_MOSIo
SPI_MISOo
NSS
SCK
MOSI
MISO
GND
Vdd
ANT
RESET
BUSY
DIO1
DIO2
RXEN
TXEN
LoRa_RESET
LoRa_BUSY
LoRa_IRQ
+3V3
C12
100n
GND
RF_OUT
PI Filter - Component Values TBD
L1
L
J8
SMA-J-P-X-RA-TH1
C14
C
C16
C
D13
ESDARF02-1BU2CK
GND

Dual control RF switches require TX enable to be tied to VDD when in single control operation.

Level Shifter

+3V3
+5V
C8
100n
R9
1k
R10
1k
U3
LSF0102
Vrefa
Vrefb
A1
A2
EN
B1
B2
I2C_SDA1
I2C_SCL1
R12
200k
C9
100n
R13
1k
R14
1k
TP12
TP13
I2C_SDA1_5V
I2C_SCL1_5V
GND

(VIH = RPU_max * (2 * pot_lkg + 1 * LSF_lkg + 1 * ADC_lkg))
===> RPU_MAX = 437.5k

Since the RP2350 is a 3.3V microcontroller, and the sensors (and associated analog ICs) run on 5V, a level shifter is required to keep the 3.3V gpio pins of the MCU safe. The SCL/SDA pins of the ADC and Digital Pots are referenced with VDD (5V) in mind.

Indicator LEDs

STATUS_LED
TX_LED
RX_LED
ERR_LED
165R
R20
165R
R19
165R
R18
75R
R17
D11
LED
D12
LED
D14
LED
D15
LED
GND

KB EELPK1.22-Q1S1-36-ABJB-020-R1B Red LED KT EELPK1.12-S2U1-25-2AY7-5-R1B Green LED

Sensor Value Readback

+5V
C10
100n
GND
U2
TMUX1309
TURB_IN
PH_IN
RTD_SEN
EXTRA_IN
S0A
S1A
S2A
S3A
TURB_GND
PH_GND
RTD_GND
EXTRA_GND
S0B
S1B
S2B
S3B
SENSOR_EN
EN
GND
Vdd
DA
DB
NC
A1
A0
SENSOR_SEL_1
SENSOR_SEL_0
TP10
TP11
Software-Defined Instrumentation Amplifier
+IN+
+IN-
SCL_5V
SDA_5V
I2C_SCL1_5V
I2C_SDA1_5V
POT0_A0
POT0_A1 0101000 [0x28]
POT0_A2
POT0 = DC offset,
POT1 = Gain
POT1_A0
POT1_A1 0101010 [0x2A]
POT1_A2
POT2_A0
POT2_A1 0101011 [0x2B]
POT2_A2
File: software_defined_inst_amp.kicad_sch
Digital Pot I2C Address: 0101 + A[210]
OUT
TP14
C7
4.7u
C15
100n
U6
MCP3425Axx-xCH
Vin+
Vin-
Vdd
Vss
SCL
SDA
I2C_SCL1_5V
I2C_SDA1_5V
I2C Address: 1101000 [0x68]

Sensor Node Control

Most ICs have their datasheets embedded. Press D to view!

USB Type B chosen because I like it. Footprint can be reduced to mini/micro B if needed.

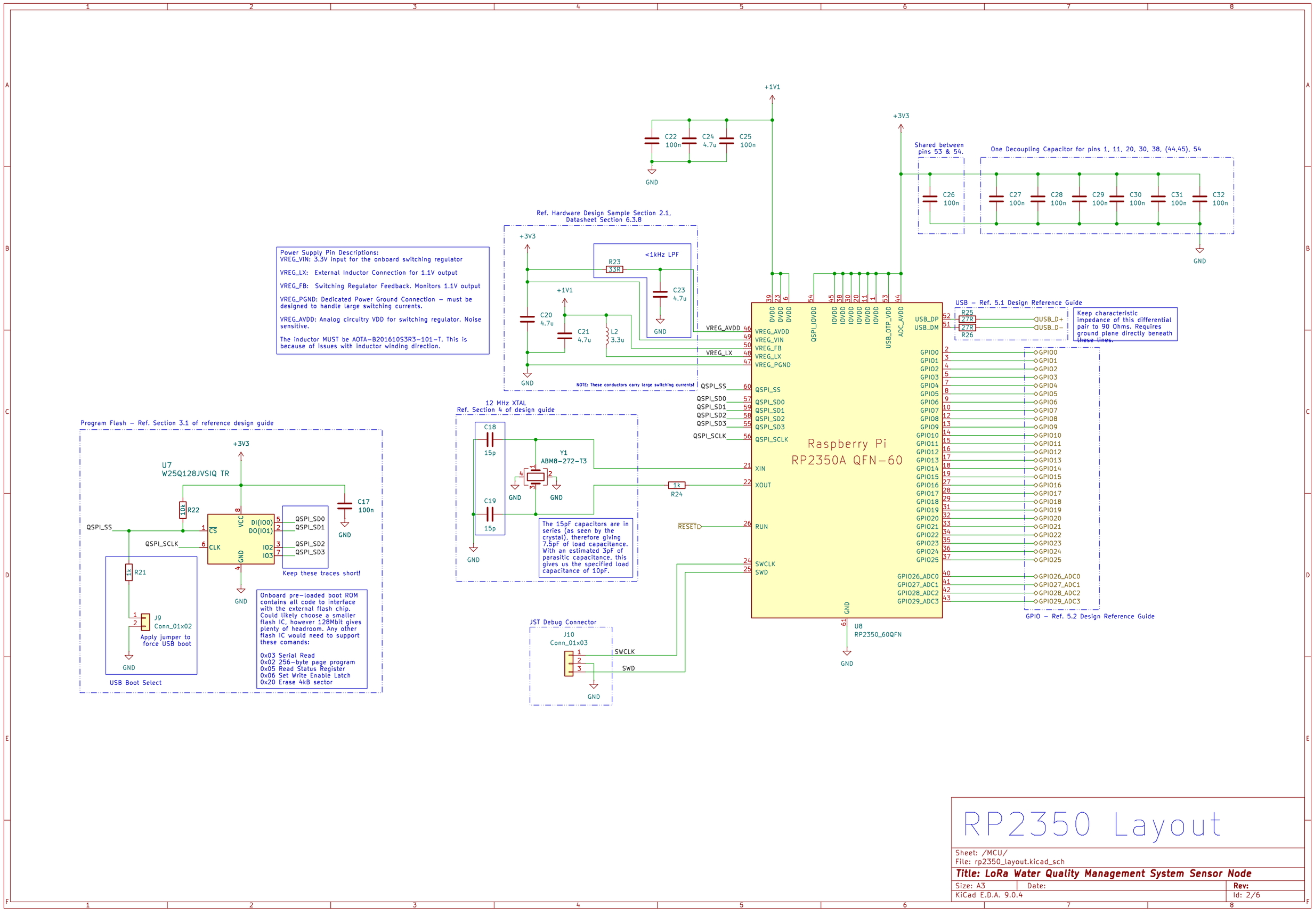
FOOTPRINT FOR USE IN CASE OF EMERGENCY!

J6
Conn_01x02
MCU
UART_TXo
UART_RXo
5V_EN
STATUS_LED
TX_LED
RX_LED
ERR_LED
FLASH_CS
LoRa_IRQ
LoRa_BUSY
LoRa_RESET
LoRa_CS
SPI_MISOo
SPI_SCKo
SPI_MOSIo
SENSOR_EN
SENSOR_SEL_0
SENSOR_SEL_1
GPIO00
GPIO01
GPIO02
GPIO03
GPIO04
GPIO05
GPIO06
GPIO07
GPIO08
GPIO09
GPIO10
GPIO11
GPIO12
GPIO13
GPIO14
GPIO15
GPIO16
GPIO17
GPIO18
GPIO19
GPIO20
GPIO21
GPIO22
GPIO23
GPIO24
GPIO25
GPIO26_ADC0
GPIO27_ADC1
GPIO28_ADC2
GPIO29_ADC3
I2C_SDA1
I2C_SCL1
File: rp2350_layout.kicad_sch
USB_VBUS
USB_D+
USB_D-
J7
USB_B
UJ2-BH-BL1-TH
VBUS
GND
Shield
+3V3
R11
10k
RESET
SW1
Tactile Pushbutton
A1
A2
B1
B2
GND
RUN
3V3_EN
ADC_VREF
AGND
VSYS
VBUS
3V3
A1
RaspberryPi_Pico
SPI_MISOo
SPI_SCKo
SPI_MOSIo
I2C_SDA1
I2C_SCL1

Sheet: /
File: LoRa Water Quality Management System Sensor Node.kicad_sch

Title: LoRa Water Quality Management System Sensor Node

Size: A2	Date:	Rev:
KiCad E.D.A. 9.0.4		Id: 1/6

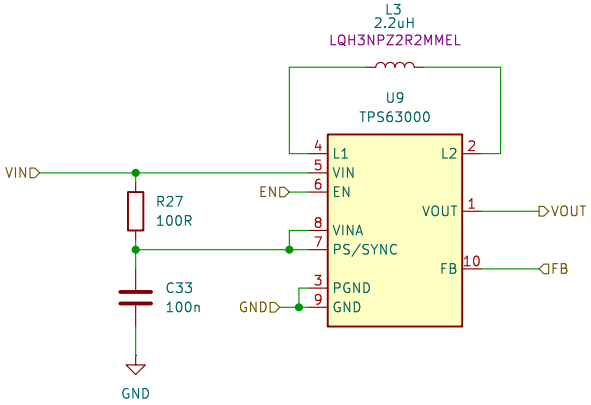

+1V1
C22 100n
C24 4.7u
C25 100n
GND
+3V3
Shared between pins 53 & 54.
One Decoupling Capacitor for pins 1, 11, 20, 30, 38, (44,45), 54
C26 100n
C27 100n
C28 100n
C29 100n
C30 100n
C31 100n
C32 100n
GND
Power Supply Pin Descriptions:
VREG_VIN: 3.3V input for the onboard switching regulator
VREG_LX: External Inductor Connection for 1.1V output
VREG_FB: Switching Regulator Feedback. Monitors 1.1V output
VREG_PGND: Dedicated Power Ground Connection – must be designed to handle large switching currents.
VREG_AVDD: Analog circuitry VDD for switching regulator. Noise sensitive.
The inductor MUST be AOTA-B201610S3R3-101-T. This is because of issues with inductor winding direction.
Ref. Hardware Design Sample Section 2.1, Datasheet Section 6.3.8
+3V3
<1kHz LPF
R23 33R
C23 4.7u
+1V1
C20 4.7u
C21 4.7u
L2 3.3u
GND
NOTE: These conductors carry large switching currents!
VREG_AVDD 46
VREG_LX 48
DVDD 39 23 6
QSPI_IOVDD 54
IOVDD 45 38 30 20 11 1
USB_OTP_VDD 53
ADC_AVDD 44
VREG_AVDD 49
VREG_VIN 50
VREG_FB
VREG_LX 47
VREG_PGND
USB – Ref. 5.1 Design Reference Guide
R25 27R
R26 27R
USB_DP 52
USB_DM 51
USB_D+
USB_D–
Keep characteristic impedance of this differential pair to 90 Ohms. Requires ground plane directly beneath these lines.
QSPI_SS 60
QSPI_SS
QSPI_SD0 57
QSPI_SD1 59
QSPI_SD2 58
QSPI_SD3 55
QSPI_SCLK 56
QSPI_SD0
QSPI_SD1
QSPI_SD2
QSPI_SD3
QSPI_SCLK
12 MHz XTAL
Ref. Section 4 of design guide
C18 15p
C19 15p
Y1 ABM8-272-T3
GND
XIN 21
XOUT 22
1k R24
The 15pF capacitors are in series (as seen by the crystal), therefore giving 7.5pF of load capacitance. With an estimated 3pF of parasitic capacitance, this gives us the specified load capacitance of 10pF.
RESET
RUN 26
SWCLK 24
SWD 25
Raspberry Pi
RP2350A QFN-60
GND 61
U8
RP2350_60QFN
GPIO0 2
GPIO1 3
GPIO2 4
GPIO3 5
GPIO4 7
GPIO5 8
GPIO6 9
GPIO7 10
GPIO8 12
GPIO9 13
GPIO10 14
GPIO11 15
GPIO12 16
GPIO13 17
GPIO14 18
GPIO15 19
GPIO16 27
GPIO17 28
GPIO18 29
GPIO19 31
GPIO20 32
GPIO21 33
GPIO22 34
GPIO23 35
GPIO24 36
GPIO25 37
GPIO26_ADC0 40
GPIO27_ADC1 41
GPIO28_ADC2 42
GPIO29_ADC3 43
GPIO – Ref. 5.2 Design Reference Guide
JST Debug Connector
J10
Conn_01x03
SWCLK
SWD
GND
Program Flash – Ref. Section 3.1 of reference design guide
+3V3
U7
W25Q128JVSIQ TR
R22 10k
C17 100n
QSPI_SS
QSPI_SCLK
CS 1
CLK 6
VCC 8
GND 4
DI(IO0) 5
DO(IO1) 2
IO2 3
IO3 7
QSPI_SD0
QSPI_SD1
QSPI_SD2
QSPI_SD3
Keep these traces short!
R21 1k
J9
Conn_01x02
Apply jumper to force USB boot
USB Boot Select
Onboard pre-loaded boot ROM contains all code to interface with the external flash chip. Could likely choose a smaller flash IC, however 128Mbit gives plenty of headroom. Any other flash IC would need to support these comands:
0x03 Serial Read
0x02 256-byte page program
0x05 Read Status Register
0x06 Set Write Enable Latch
0x20 Erase 4kB sector
RP2350 Layout
Sheet: /MCU/
File: rp2350_layout.kicad_sch
Title: LoRa Water Quality Management System Sensor Node
Size: A3
Date:
Rev:
KiCad E.D.A. 9.0.4
Id: 2/6

Maximum Current Throughput:

RP2350: ~100mA max
sx1262: 118mA max in +22dBm TX Mode
+200mA headroom

Let's call it 500mA expected worst case input current. Most of the time we will be in sleep mode and never come close to this.

Energizer considers the useable life of their D-Cell batteries to be up to 0.8V, meaning a minimum expected input voltage of 2.4V is reasonable. To add some factor of safety, I'll do the calculations with 2V input:



Power Supply

Sheet: /Buck-Boost Regulator Layout/
File: lwqms_power_supply.kicad_sch

Title: LoRa Water Quality Management System Sensor Node

Size: A4	Date:	Rev:
KiCad E.D.A. 9.0.4		Id: 3/6

Maximum Current Throughput:

RP2350: ~100mA max
sx1262: 118mA max in +22dBm TX Mode
+200mA headroom

Let's call it 500mA expected worst case input current. Most of the time we will be in sleep mode and never come close to this.

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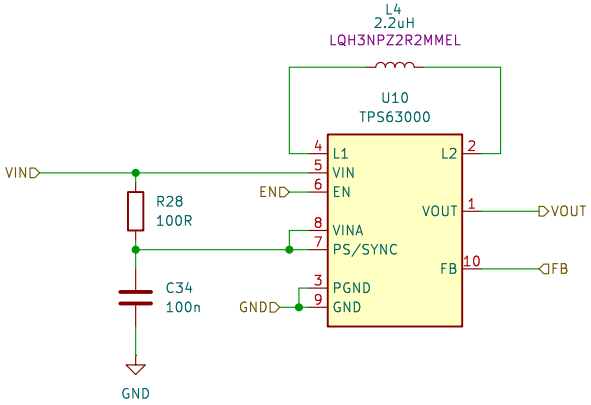
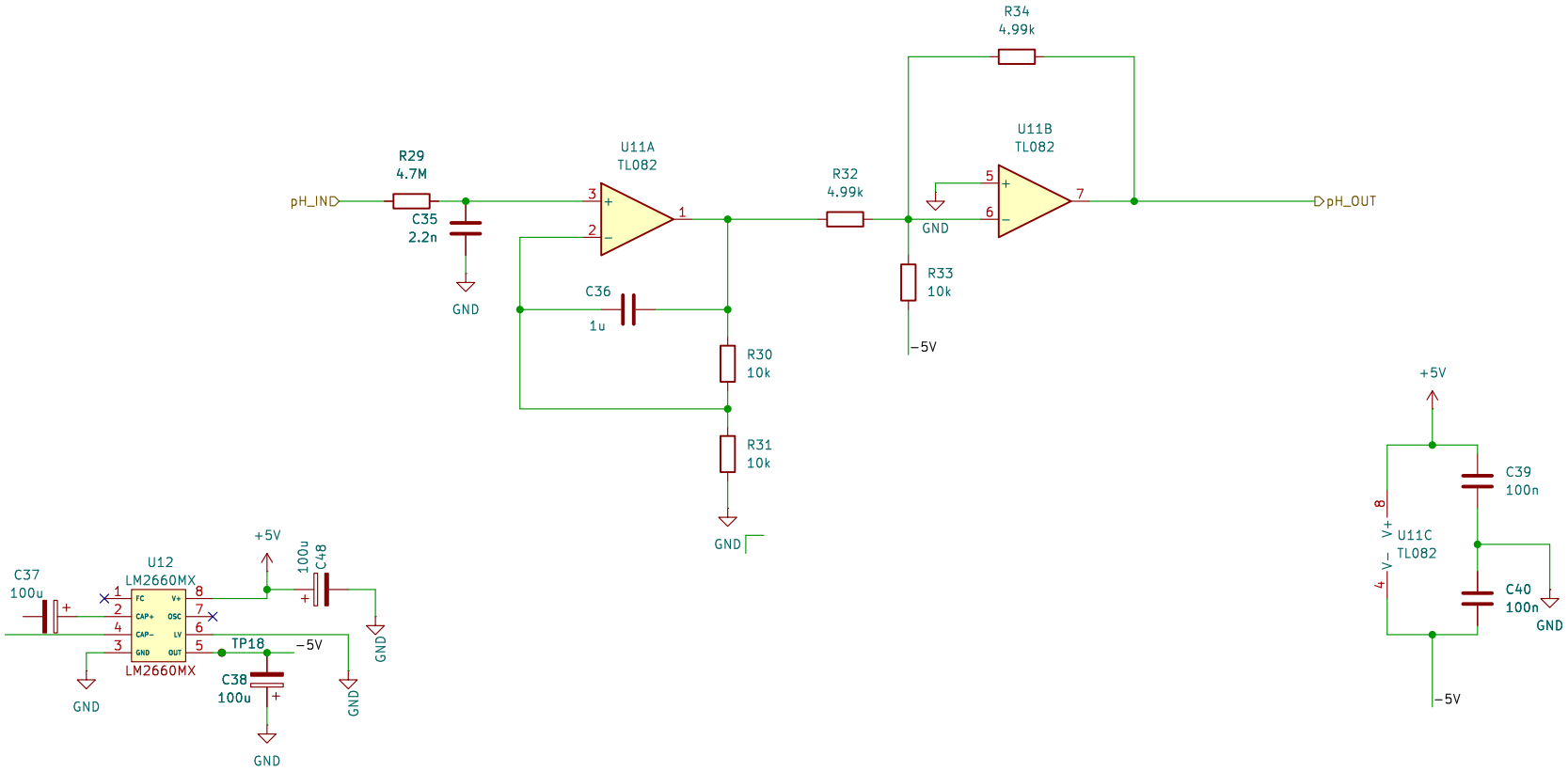


Power Supply

Sheet: /Buck-Boost Regulator Layout1/
File: lwqms_power_supply.kicad_sch

Title: LoRa Water Quality Management System Sensor Node

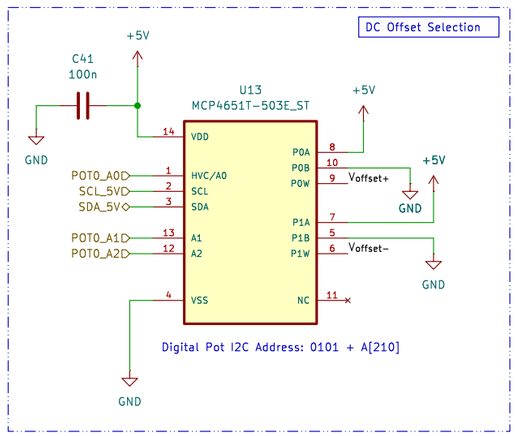
Size: A4	Date:	**Rev:**
KiCad E.D.A. 9.0.4		Id: 4/6

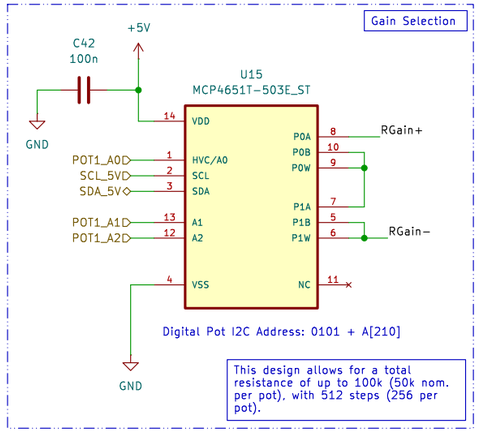


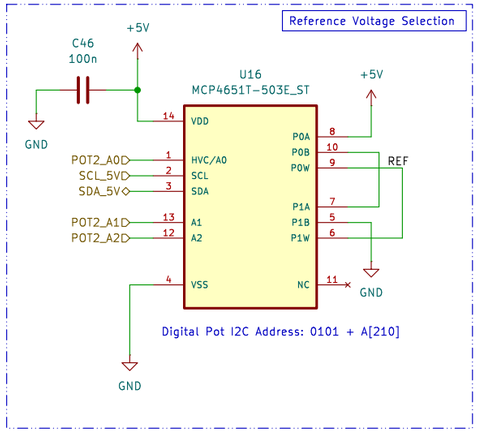
pH Sensor Pre−Amplifier

Sheet: /PH Sensor Pre−Amplifier ALT/	
File: phsensorboard_alt.kicad_sch	
Title: LoRa Water Quality Management System Sensor Node	
Size: A4	Date:
KiCad E.D.A. 9.0.4	Id: 5/6

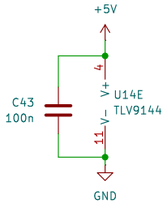
Software-Defined Instrumentation Amplifier



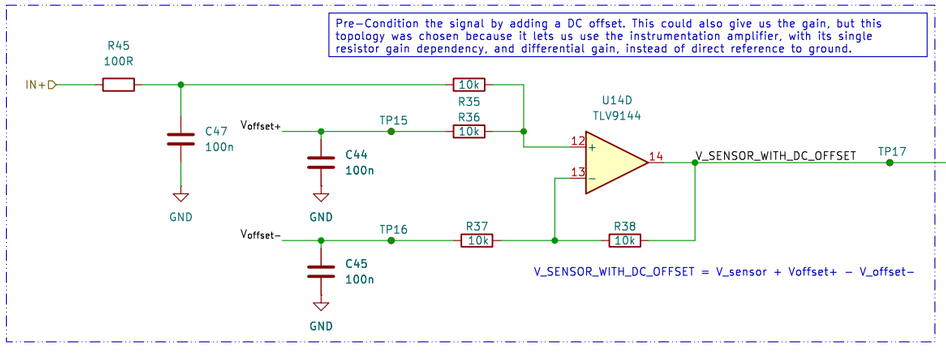


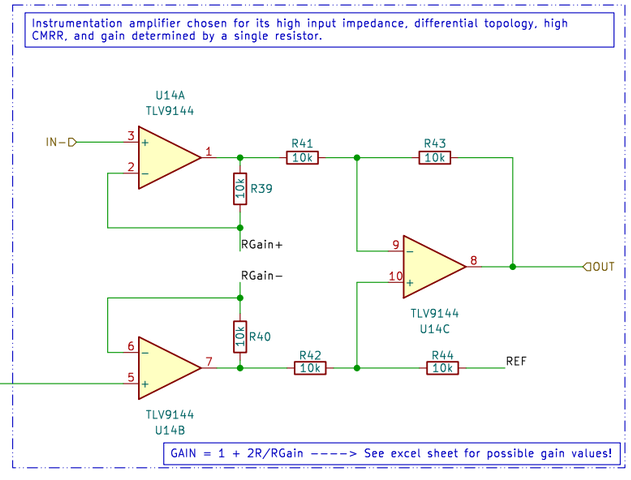


Vout = (Vin+ + V_OFFSET+ - V_OFFSET- - Vin-)(20K/R_GAIN + 1) + VREF



LMV324A op amp chosen as its output voltage can be within 20mV (typ.) of its input rails. High CMRR, quad package, and 44 cents per IC are a plus.





Sheet: /Software-Defined Instrumentation Amplifier/		
File: software_defined_inst_amp.kicad_sch		
Title: LoRa Water Quality Management System Sensor Node		
Size: A3	Date:	**Rev:**
KiCad E.D.A. 9.0.4		Id: 6/6