Power Plant - Schematics - Templates

These lecture notes created by Mr. James B. (Jim) Carlson, NCSU

Today

- Power Plant?
- Schematics?
- Project Write-up?

Power Supply

- What do we need (voltage and current)? Look at manual for voltage and current for microcontroller and other circuits

Recommended Operating Conditions

Typical values are specified at V_{CC} = 3.3 V and T_A = 25°C (unless otherwise noted)

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage during program execution and FRAM programming (AVCC = DVCC) [1]		2.0		3.6	V
V_{SS}	Supply voltage (AVSS = DVSS)			0		V
T_A	Operating free-air temperature	I version	-40		85	°C
T_J	Operating junction temperature	I version	-40		85	°C
C_{VCORE}	Required capacitor at VCORE			470		nF
C_{VCC}/ C_{VCORE}	Capacitor ratio of VCC to VCORE		10			
f_{SYSTEM}	Processor frequency (maximum MCLK frequency) [2]	No FRAM wait states [3], 2 V ≤ V_{CC} ≤ 3.6 V	0		8.0	MHz
		With FRAM wait states [3], NACCESS = {2}, NPRECHG = {1}, 2 V ≤ V_{CC} ≤ 3.6 V	0		24.0	

(1) It is recommended to power AVCC and DVCC from the same source. A maximum difference of 0.3 V between AVCC and DVCC can be tolerated during power up and operation.
(2) Modules may have a different maximum input clock specification. See the specification of the respective module in this data sheet.
(3) When using manual wait state control, see the *MSP430FR57xx Family User's Guide* (SLAU272) for recommended settings for common system frequencies.

Power Supply

- What do we need (voltage and current)? Look at manual for voltage and current for microcontroller and other circuits

Active Mode Supply Current Into V_{CC} Excluding External Current

over recommended operating free-air temperature (unless otherwise noted) (1) (2) (3)

PARAMETER	EXECUTION MEMORY	V_{CC}	Frequency ($f_{MCLK} = f_{SMCLK}$) (4)												UNIT
			1 MHz		4 MHz		8 MHz		16 MHz (5)		20 MHz (5)		24 MHz (5)		
			TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
$I_{AM,\ FRAM\_UNI}$ (6)	FRAM	3 V	0.27		0.58		1.0		1.53		1.9		2.2		mA
$I_{AM,0\%}$ (7)	FRAM 0% cache hit ratio	3 V	0.42	0.73	1.2	1.6	2.2	2.8	2.3	2.9	2.8	3.6	3.45	4.3	mA
$I_{AM,50\%}$ (7) (8)	FRAM 50% cache hit ratio	3 V	0.31		0.73		1.3		1.75		2.1		2.5		
$I_{AM,66\%}$ (7) (8)	FRAM 66% cache hit ratio	3 V	0.27		0.58		1.0		1.55		1.9		2.2		
$I_{AM,75\%}$ (7) (8)	FRAM 75% cache hit ratio	3 V	0.25		0.5		0.82		1.3		1.6		1.8		
$I_{AM,100\%}$ (7) (8)	FRAM 100% cache hit ratio	3 V	0.2	0.43	0.3	0.55	0.42	0.8	0.73	1.15	0.88	1.3	1.0	1.5	
$I_{AM,\ RAM}$ (8) (9)	RAM	3 V	0.2	0.4	0.35	0.55	0.55	0.75	1.0	1.25	1.20	1.45	1.45	1.75	mA

Power Supply

- What do we need (voltage and current)? Look at manual for voltage and current for microcontroller and other circuits

(1) All inputs are tied to 0 V or to V_{CC}. Outputs do not source or sink any current.
(2) The currents are characterized with a Micro Crystal CC4V-T1A SMD crystal with a load capacitance of 9 pF. The internal and external load capacitance are chosen to closely match the required 9 pF.
(3) Characterized with program executing typical data processing.
(4) At MCLK frequencies above 8 MHz, the FRAM requires wait states. When wait states are required, the effective MCLK frequency, $f_{MCLK,eff}$, decreases. The effective MCLK frequency is also dependent on the cache hit ratio. SMCLK is not affected by the number of wait states or the cache hit ratio. The following equation can be used to compute $f_{MCLK,eff}$:
$f_{MCLK,eff,MHZ} = f_{MCLK,MHZ}$ x 1 / [# of wait states x ((1 - cache hit ratio percent/100)) + 1]
(5) MSP430FR573x series only
(6) Program and data reside entirely in FRAM. No wait states enabled. DCORSEL = 0, DCOFSELx = 3 (f_{DCO} = 8 MHz). MCLK = SMCLK.
(7) Program resides in FRAM. Data resides in SRAM. Average current dissipation varies with cache hit-to-miss ratio as specified. Cache hit ratio represents number cache accesses divided by the total number of FRAM accesses. For example, a 25% ratio implies one of every four accesses is from cache, the remaining are FRAM accesses.
For 1, 4, and 8 MHz, DCORSEL = 0, DCOFSELx = 3 (f_{DCO} = 8 MHz). MCLK = SMCLK. No wait states enabled.
For 16 MHz, DCORSEL = 1, DCOFSELx = 0 (f_{DCO} = 16 MHz).MCLK = SMCLK. One wait state enabled.
For 20 MHz, DCORSEL = 1, DCOFSELx = 2 (f_{DCO} = 20 MHz).MCLK = SMCLK. Three wait states enabled.
For 24 MHz, DCORSEL = 1, DCOFSELx = 3 (f_{DCO} = 24 MHz).MCLK = SMCLK. Three wait states enabled.
(8) See Figure 1 for typical curves. Each characteristic equation shown in the graph is computed using the least squares method for best linear fit using the typical data shown in Active Mode Supply Current Into V_{CC} Excluding External Current.
f_{ACLK} = 32786 Hz, $f_{MCLK} = f_{SMCLK}$ at specified frequency. No peripherals active.
XTS = CPUOFF = SCG0 = SCG1 = OSCOFF= SMCLKOFF = 0.
(9) All execution is from RAM.
For 1, 4, and 8 MHz, DCORSEL = 0, DCOFSELx = 3 (f_{DCO} = 8 MHz). MCLK = SMCLK.
For 16 MHz, DCORSEL = 1, DCOFSELx = 0 (f_{DCO} = 16 MHz). MCLK = SMCLK.
For 20 MHz, DCORSEL = 1, DCOFSELx = 2 (f_{DCO} = 20 MHz). MCLK = SMCLK.
For 24 MHz, DCORSEL = 1, DCOFSELx = 3 (f_{DCO} = 24 MHz). MCLK = SMCLK.

Power Supply

- Where do we get the power?
- Plug into wall
  - Wall - Need to drop 120 VAC to Low Voltage VDC
    - Transformer-based
    - Switching
- Use batteries
  - Battery Voltage changes with discharge
    - Conversion from variable voltage to constant voltage
      - Regulator
      - Switcher

Batteries

- Battery ≡ >1 cell
- Cell can be modeled as ideal voltage source with a series resistance
  - Series resistance induces a voltage drop as current rises
- How long will it last?
  - Cells can be modeled as having a constant capacity (1 amp-hour = 3600 coulombs = 3600 amp-seconds) *(less accurate)*
    - Battery life (hours) = capacity (amp-hours)/current (amps)
  - Can also predict life based on discharge plot *(more accurate)*
- What if voltage or current isn't right?
  - Can put cells in series (add voltages) or parallel (add currents)
  - Can use a voltage regulator (linear or switch-mode)

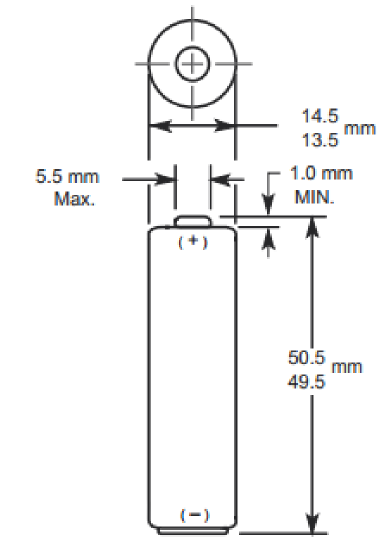
Battery Power

- A 800 mAhr battery will power a device that draws 200mA for how long?
  800 mAhr / 200mA = 4 hr

- What is the voltage of a "AA" battery?

- What is the current capabilities?

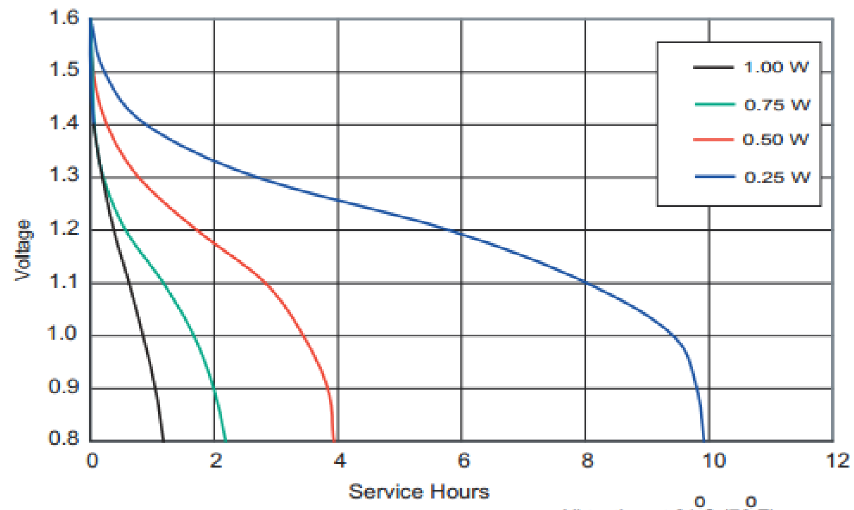
Battery Power



Dimensions shown are ANSI standards

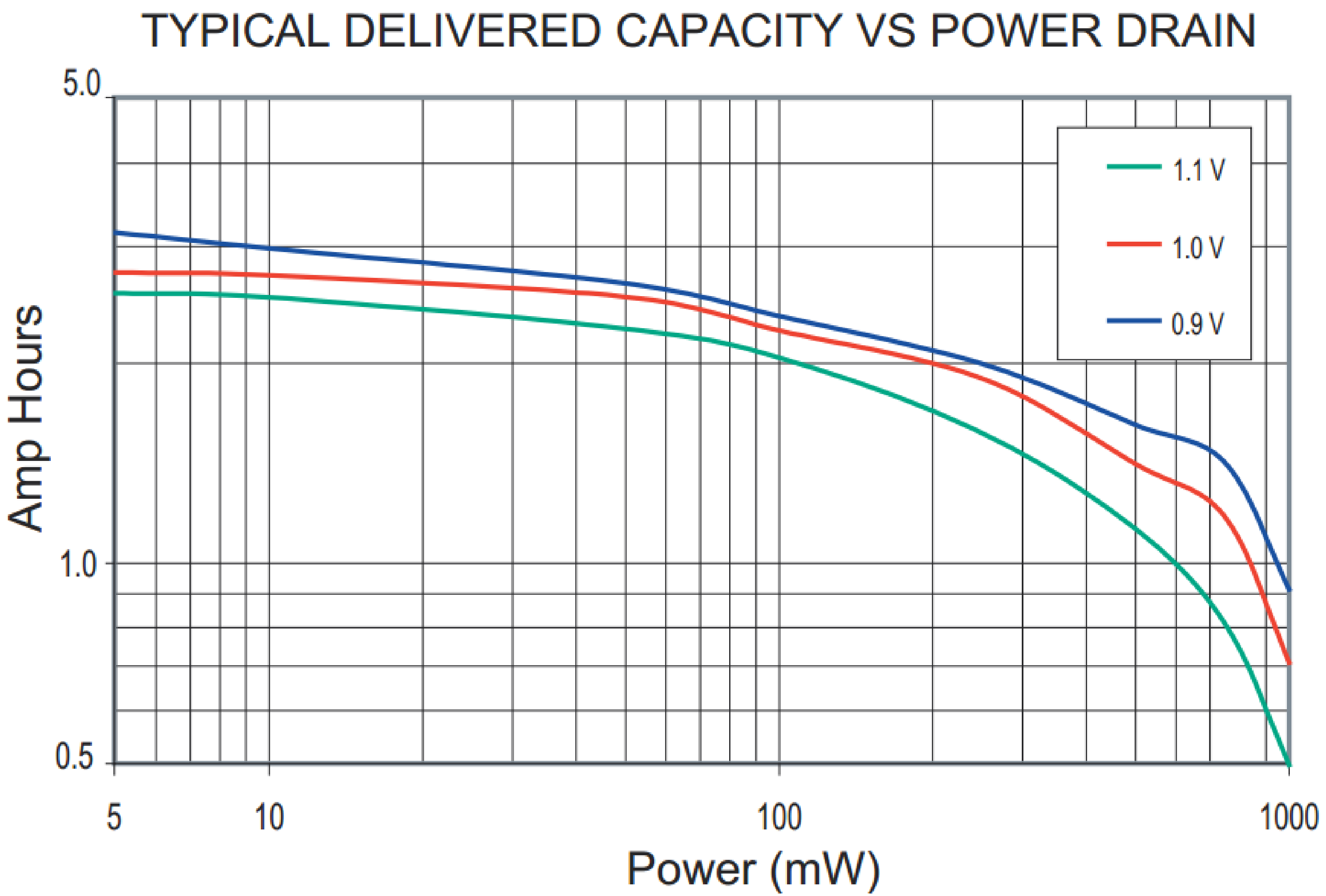
Nominal Voltage:	1.5 V
Operating Voltage	1.6 - 0.75V
Impedance:	81 m-ohm @ 1kHz
Typical Weight:	24 gm (0.8 oz.)
Typical Volume:	8.4 cm^3 (0.5 $in.^3$)
Terminals:	Flat
Storage Temperature Range:	-20 °C to 35 °C
Operating Temperature Range:	-20 °C to 54 °C (-4 °F to 130 °F)
ANSI: **IEC:**	15A LR6

TYPICAL DISCHARGE CHARACTERISTICS AT VARIOUS POWER DRAINS

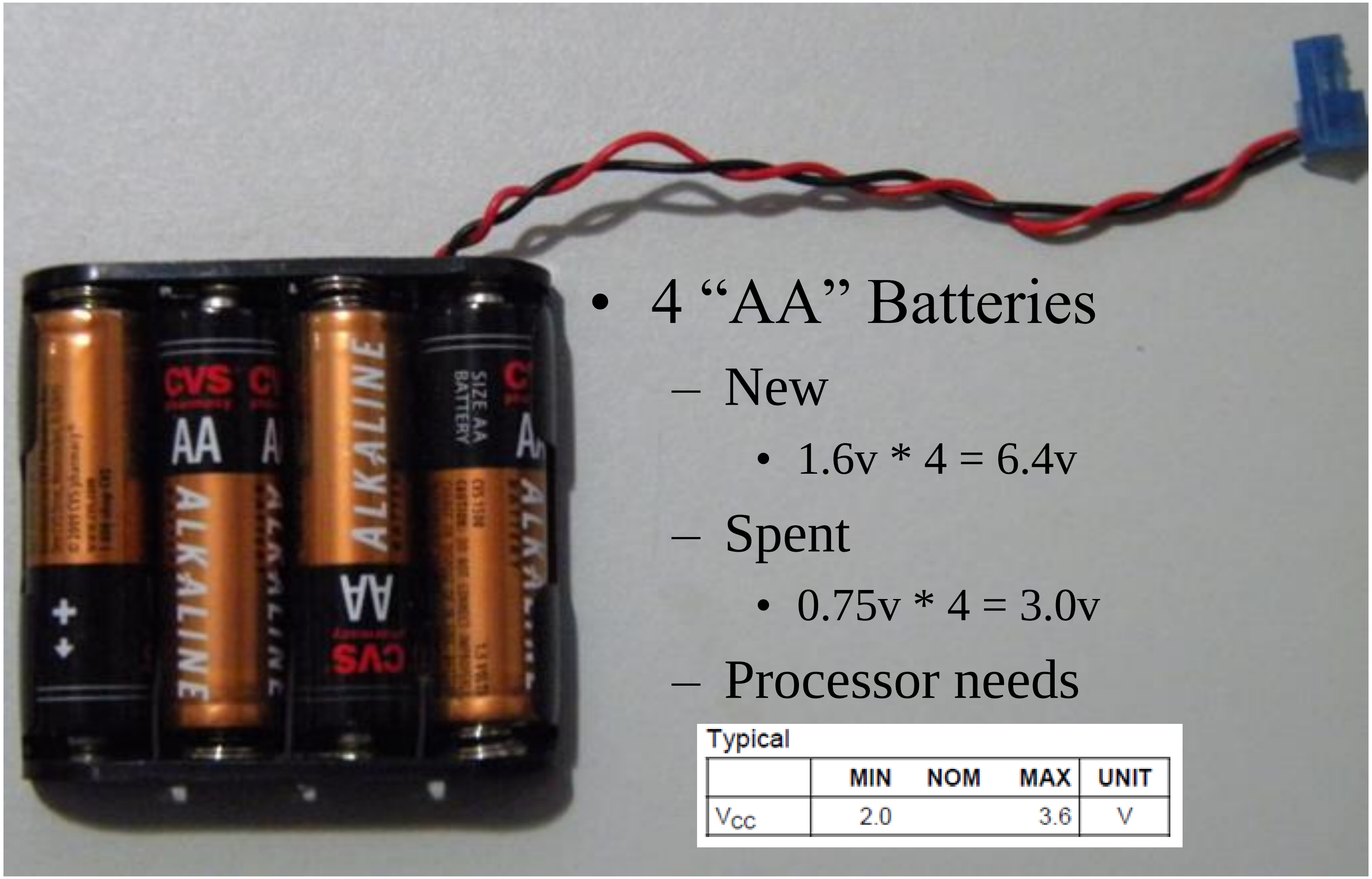


All testing at 21 °C (70 °F)

Battery Power



Battery Power

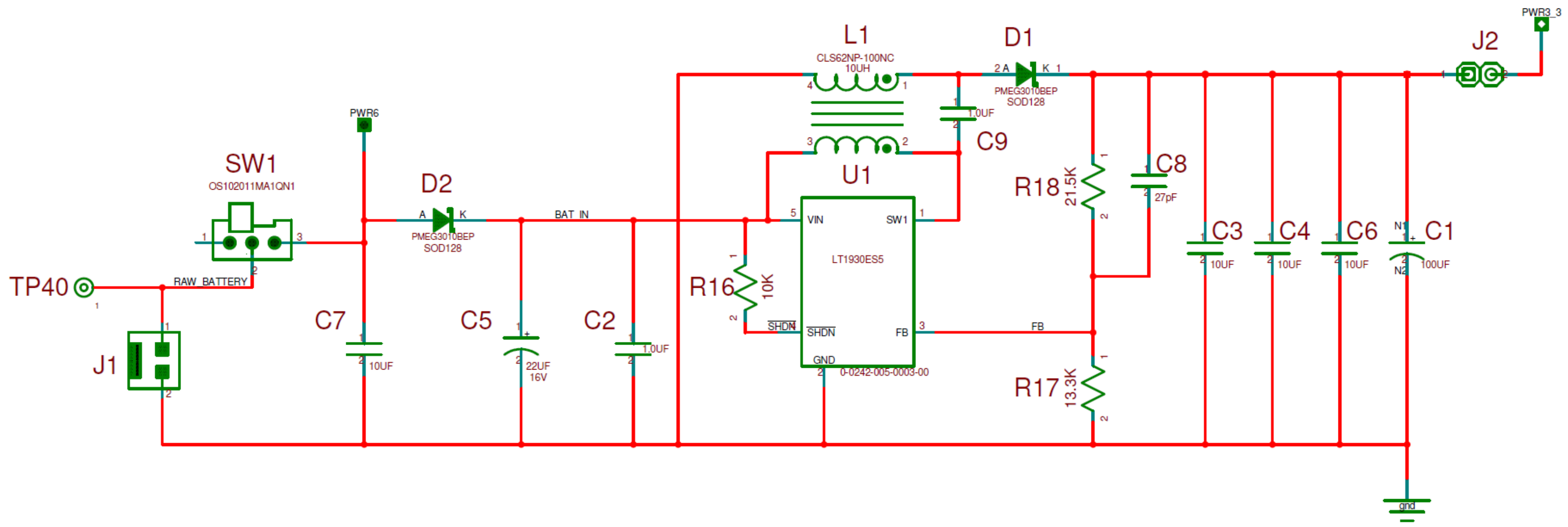


- 4 “AA” Batteries
  - New
    - 1.6v * 4 = 6.4v
  - Spent
    - 0.75v * 4 = 3.0v
  - Processor needs

Typical

	MIN	NOM	MAX	UNIT
V_{CC}	2.0		3.6	V

Battery Power



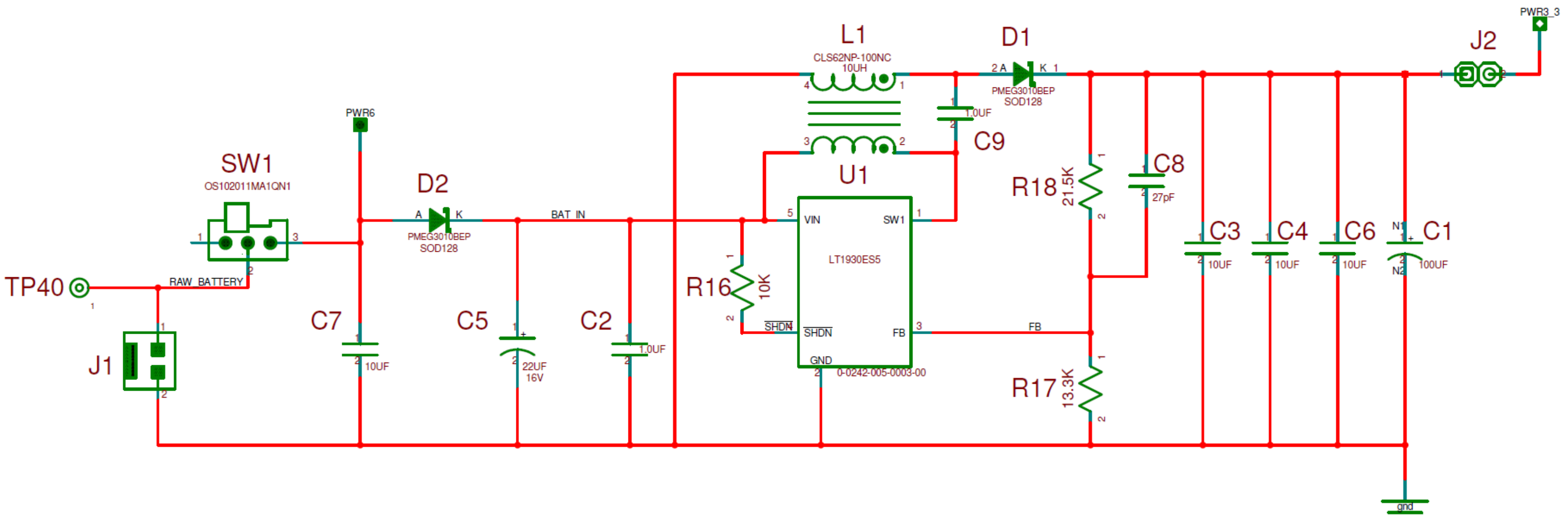
Boost Converter as Sepic Converter

Battery Power

Single Inductor
Regulated Output with Input Voltages
Above, Below or Equal to the Output
Wide VIN Range: 2.6V to 16V
VOUT Range: 2.4V to 5.25V
Low Shutdown Current: <1uA
Low Profile (1mm) ThinSOT Package

Battery Power

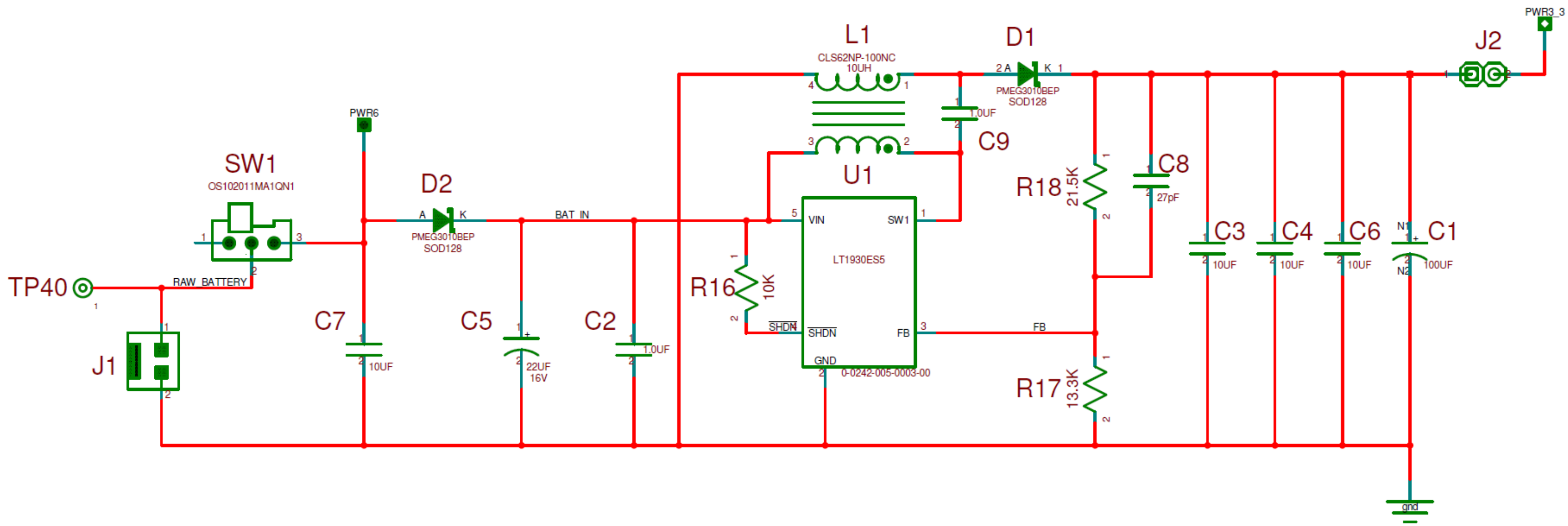
- Wide VIN Range: 2.6V to 16V



Battery Power

- Wide VIN Range: 2.6V to 16V

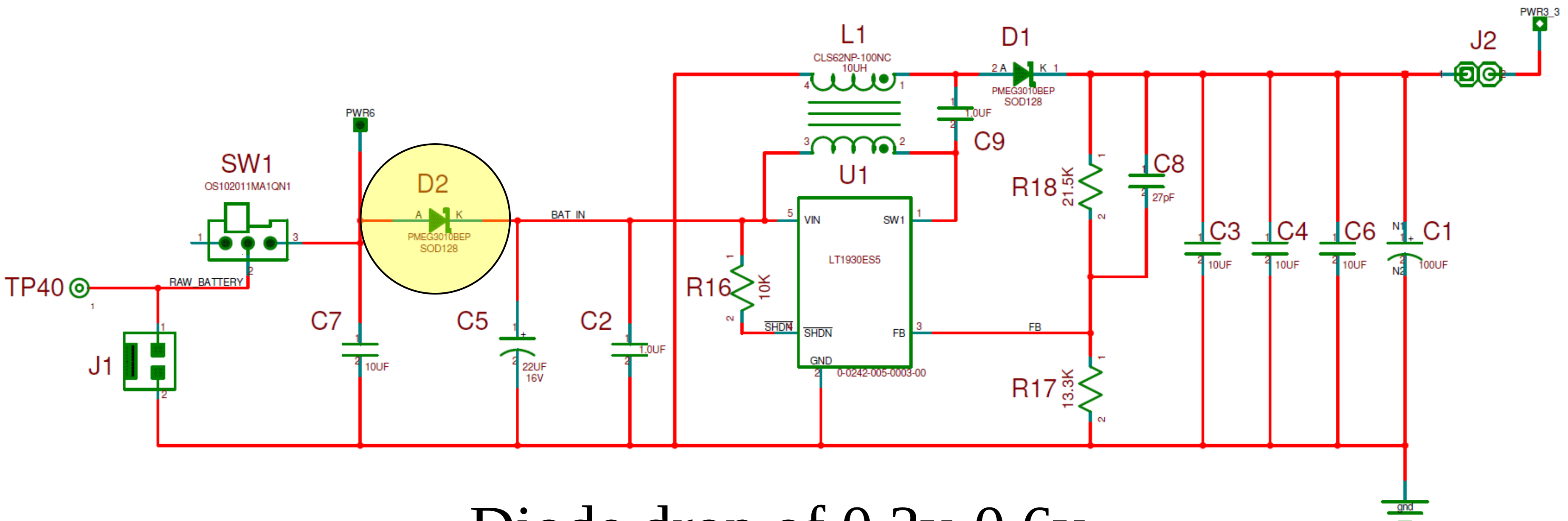
4 “AA” Batteries ~ 6v



Battery Power

- **Wide VIN Range: 2.6V to 16V**

4 “AA” Batteries ~ 6v



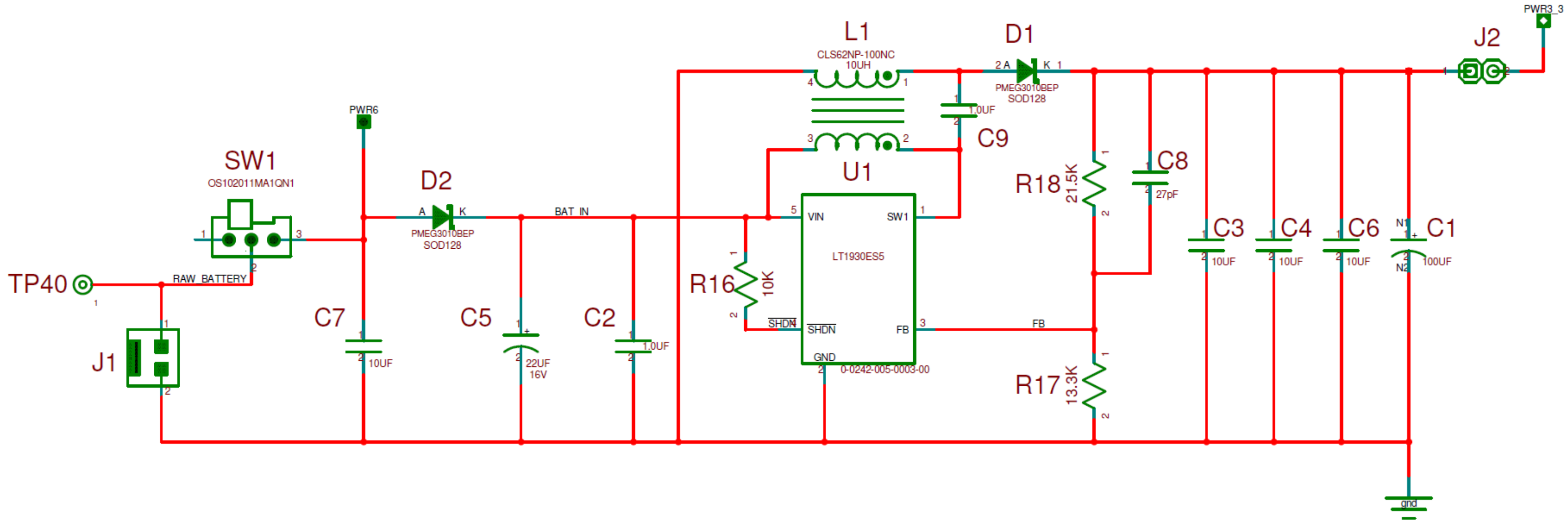
Diode drop of 0.3v-0.6v

P-FET drop 0.1-0.3v

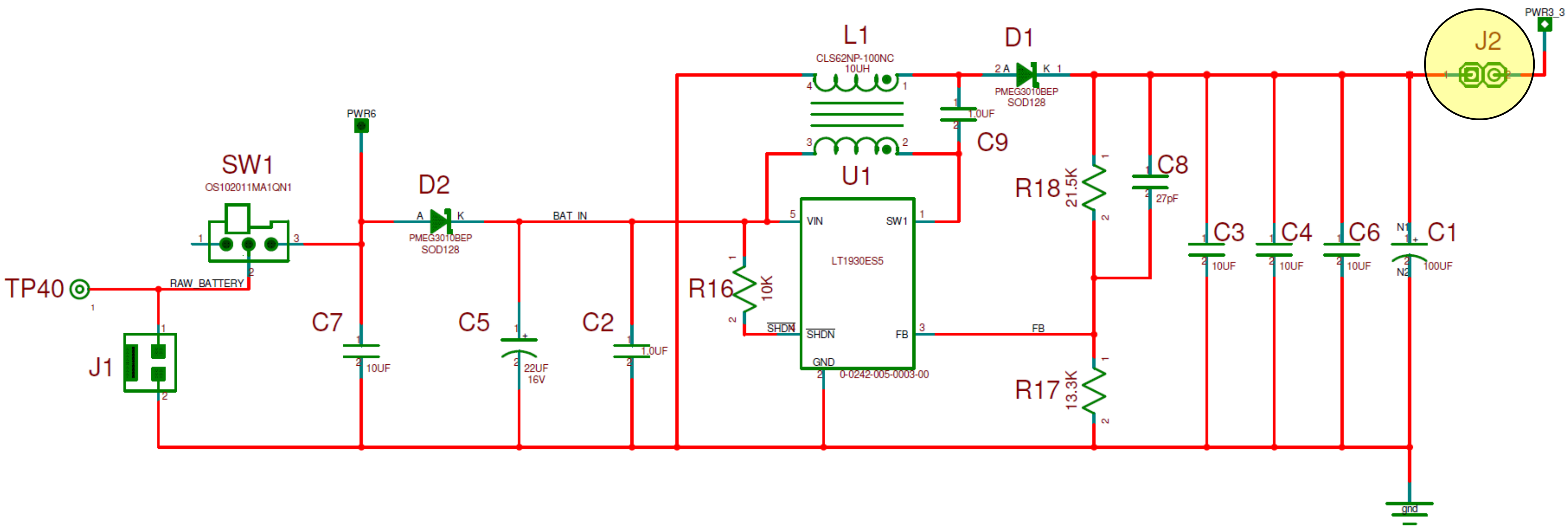
Protection against Batteries installed backward

Battery Power

- Synchronous Rectification: Up to 87% Efficiency

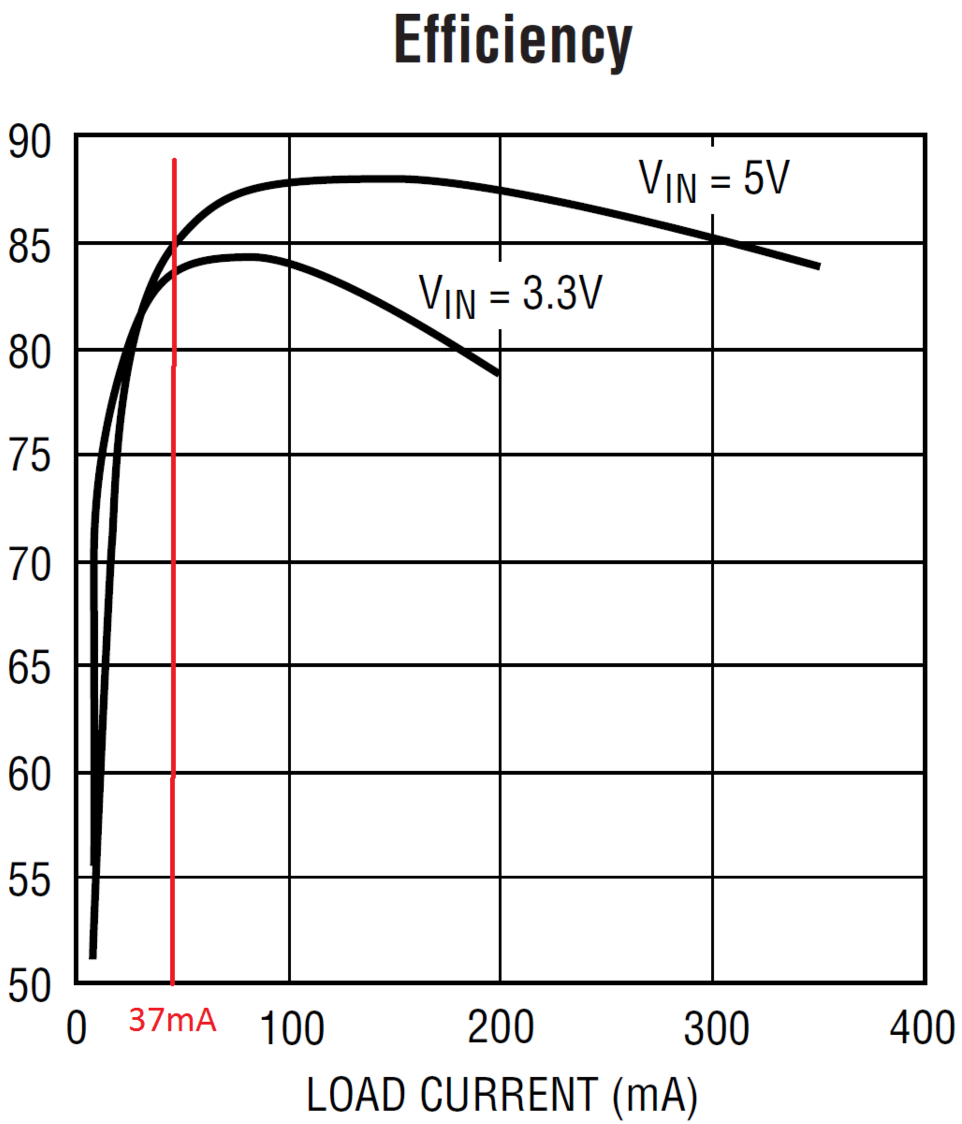


Battery Power

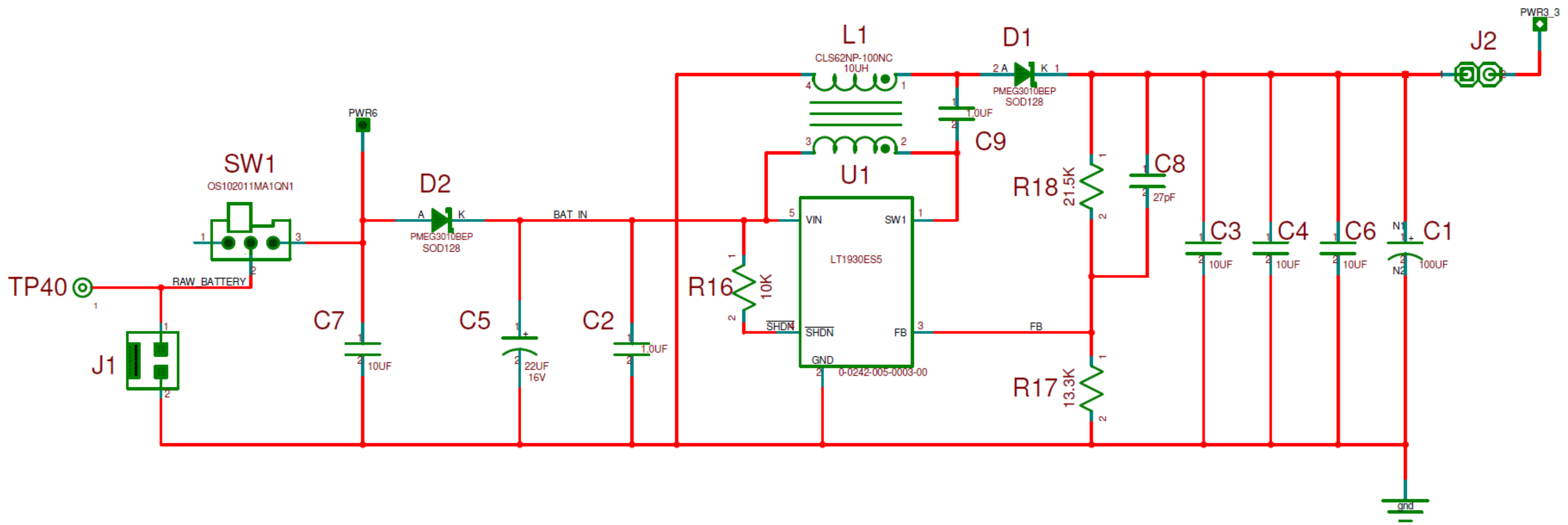


If you measure the current into the load as 31ma, measured at J2.
How long will the batteries last with continuous use?

Battery Power



Battery Power



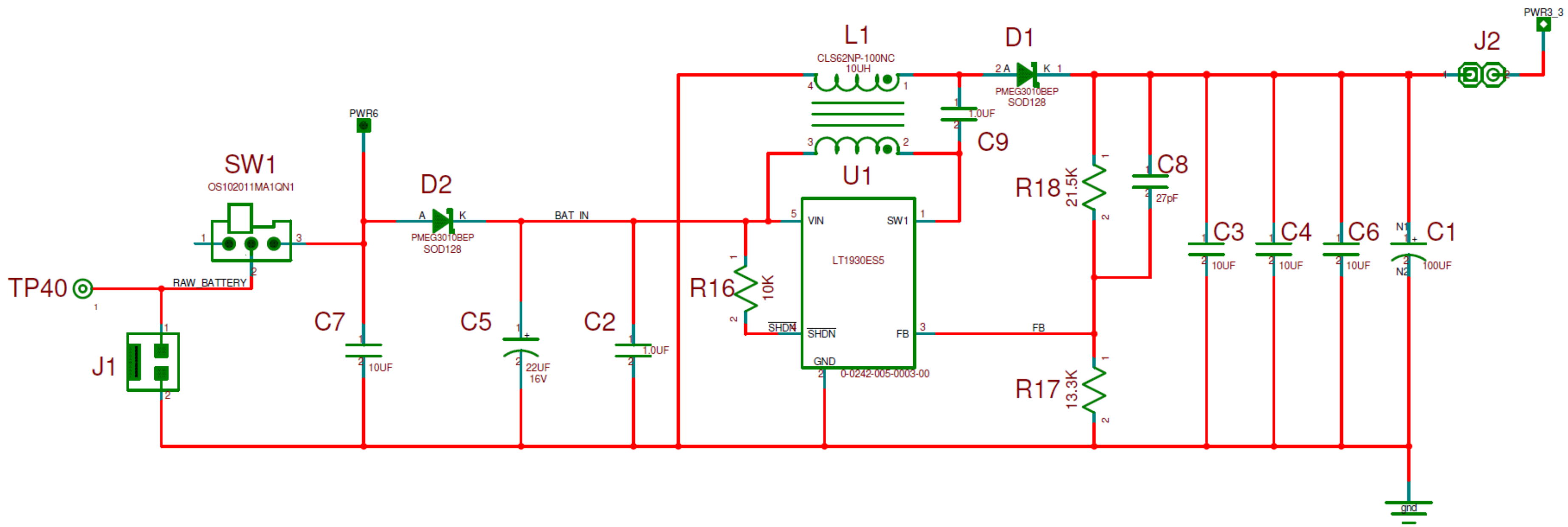
Voltage = Current * Resistance

Power = Voltage * Current

Battery Voltage changes – What about current?

How can you solve this problem?

Battery Power

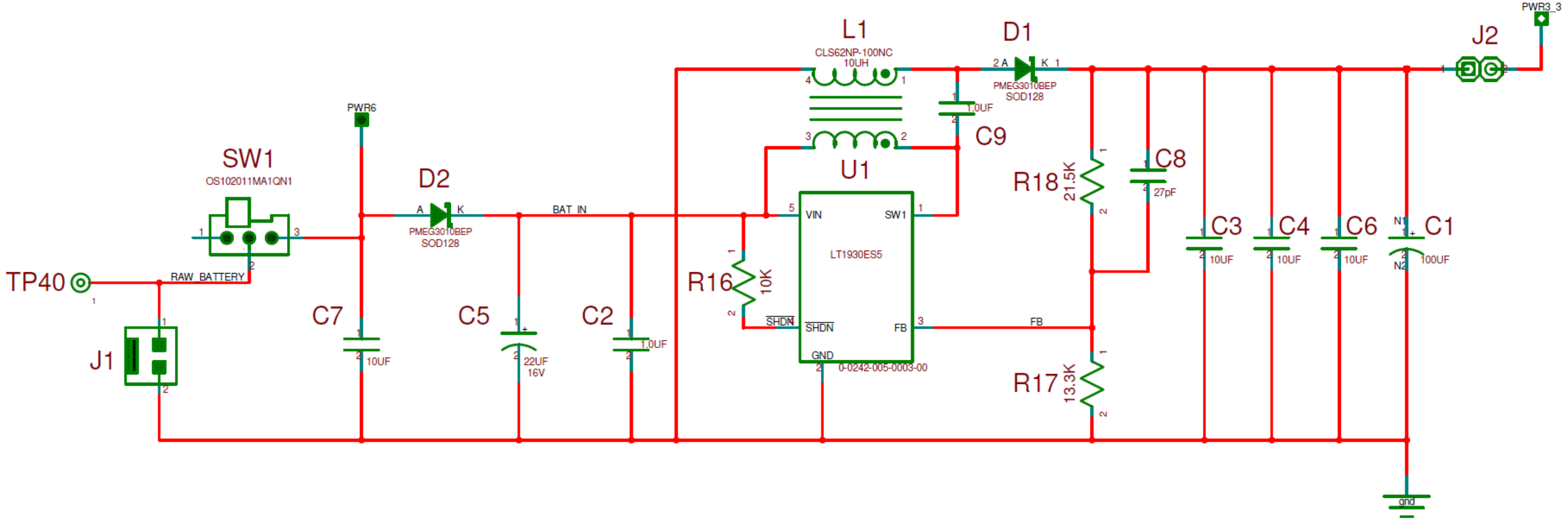


Voltage = 3.3v Current = 31mA

Power = 3.3v * 31mA ➔ 102.3mW

Battery Power

- **Synchronous Rectification: From Graph ~85% Efficient**



Voltage = 3.3v Current = 31mA

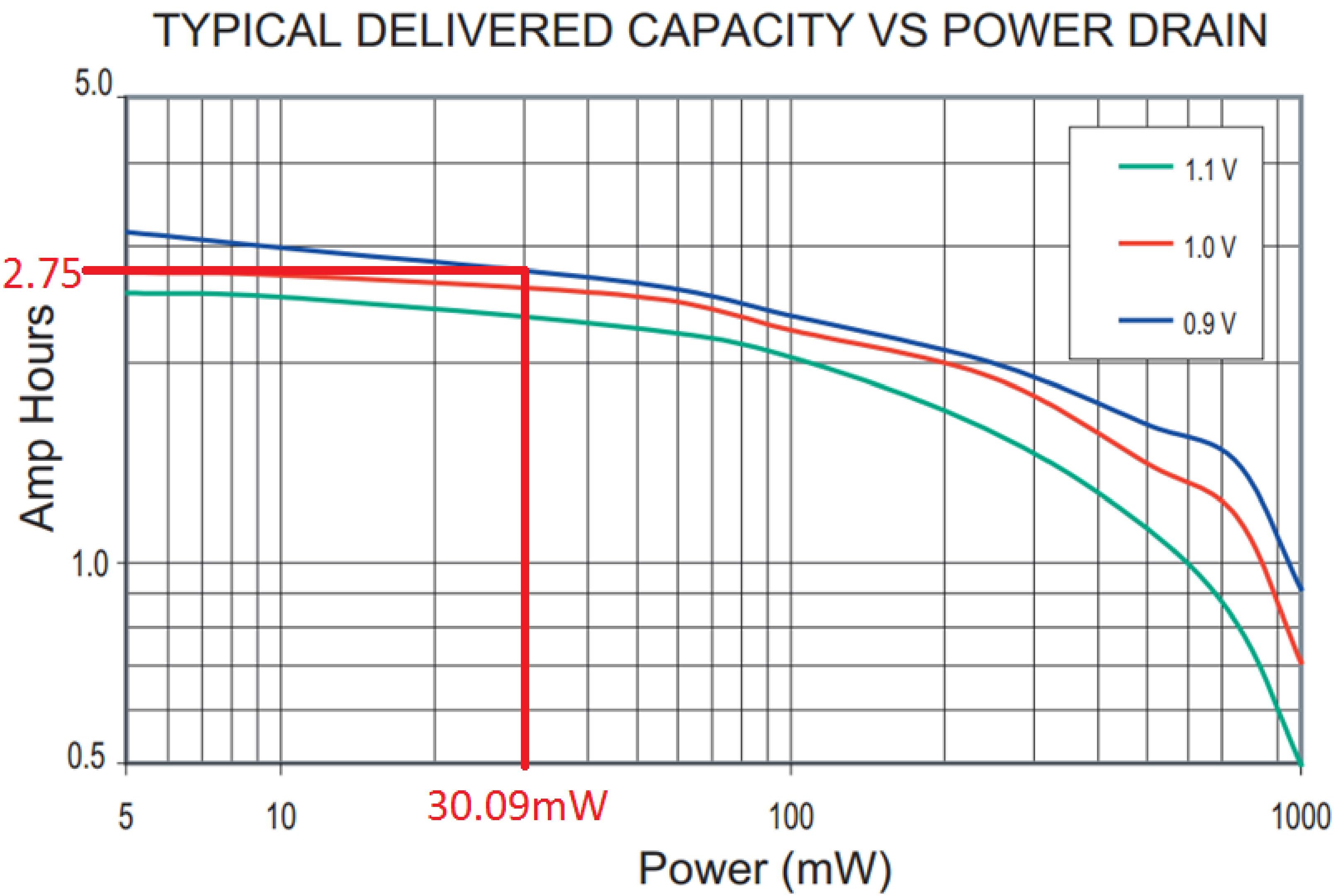
Power = 3.3v * 31mA ➔ 102.3mW

102.3 mW / 85% efficiency = 120.35mW from Batteries

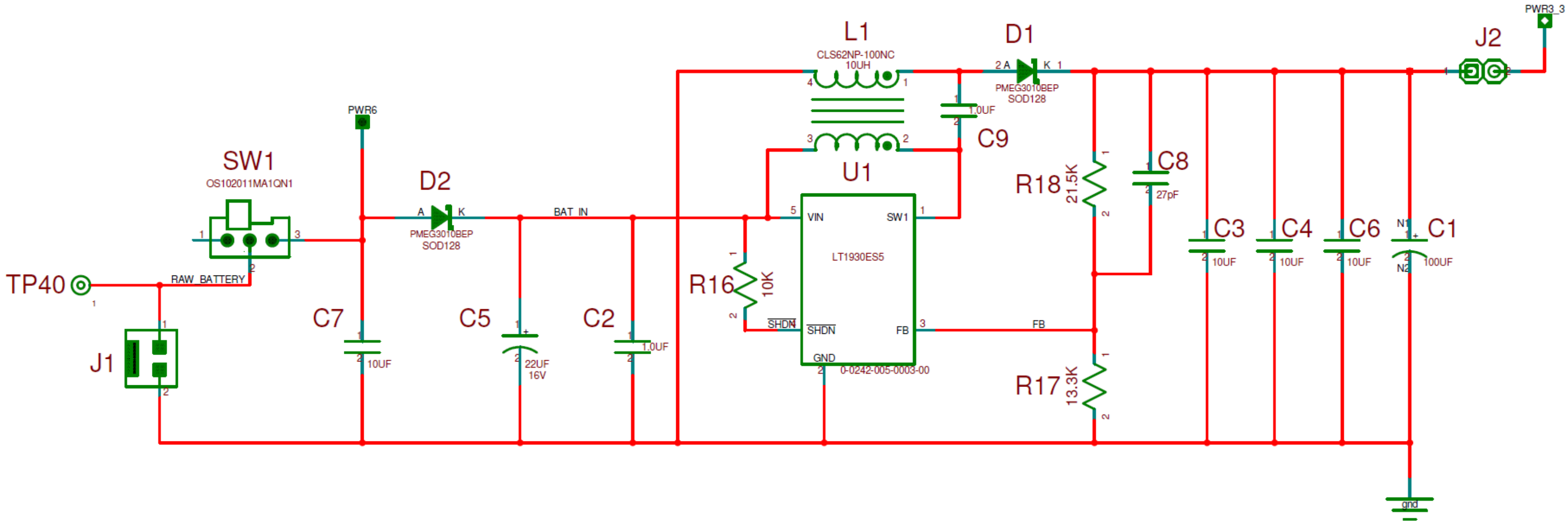
With 4 Batteries –

120.35mW / 4 batteries = 30.09mW per battery

Battery Power

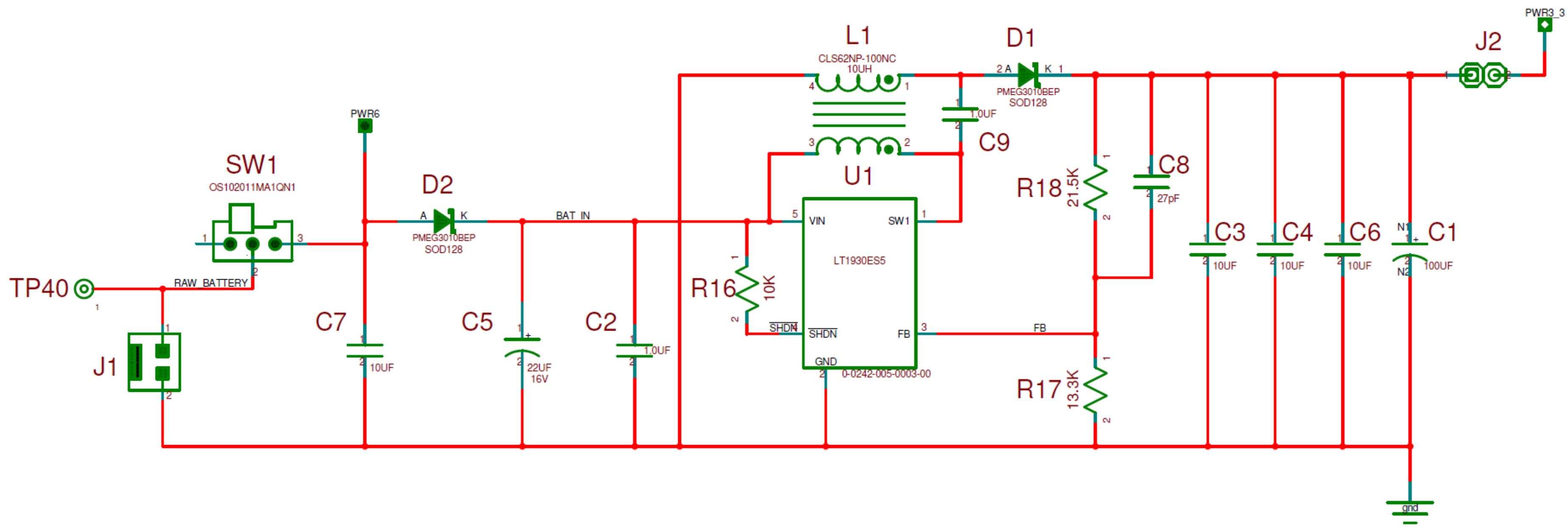


Battery Power

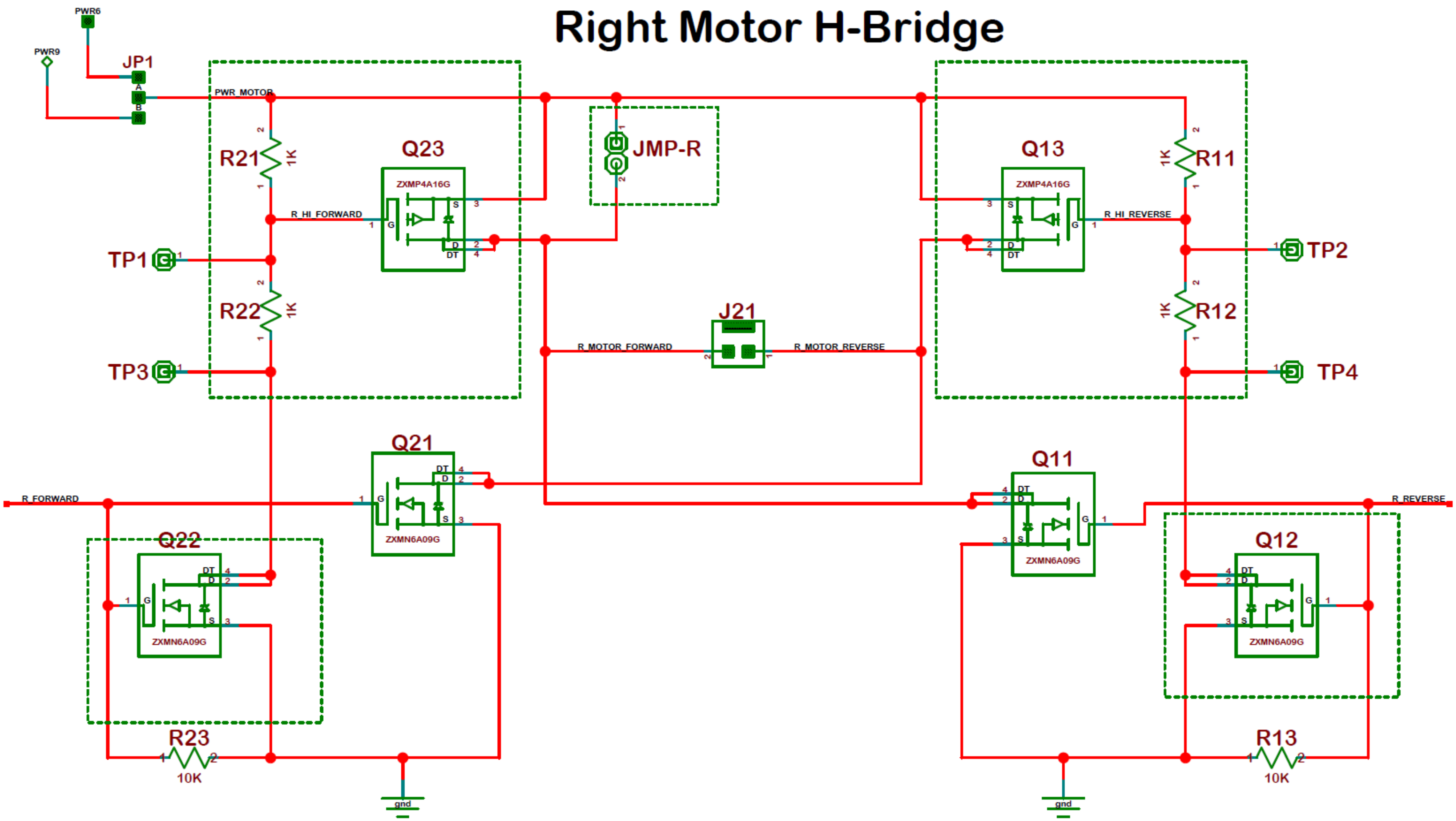


Time = 2.75 Amp-Hour / 0.031 Amp = **88.7 Hours**

Schematics

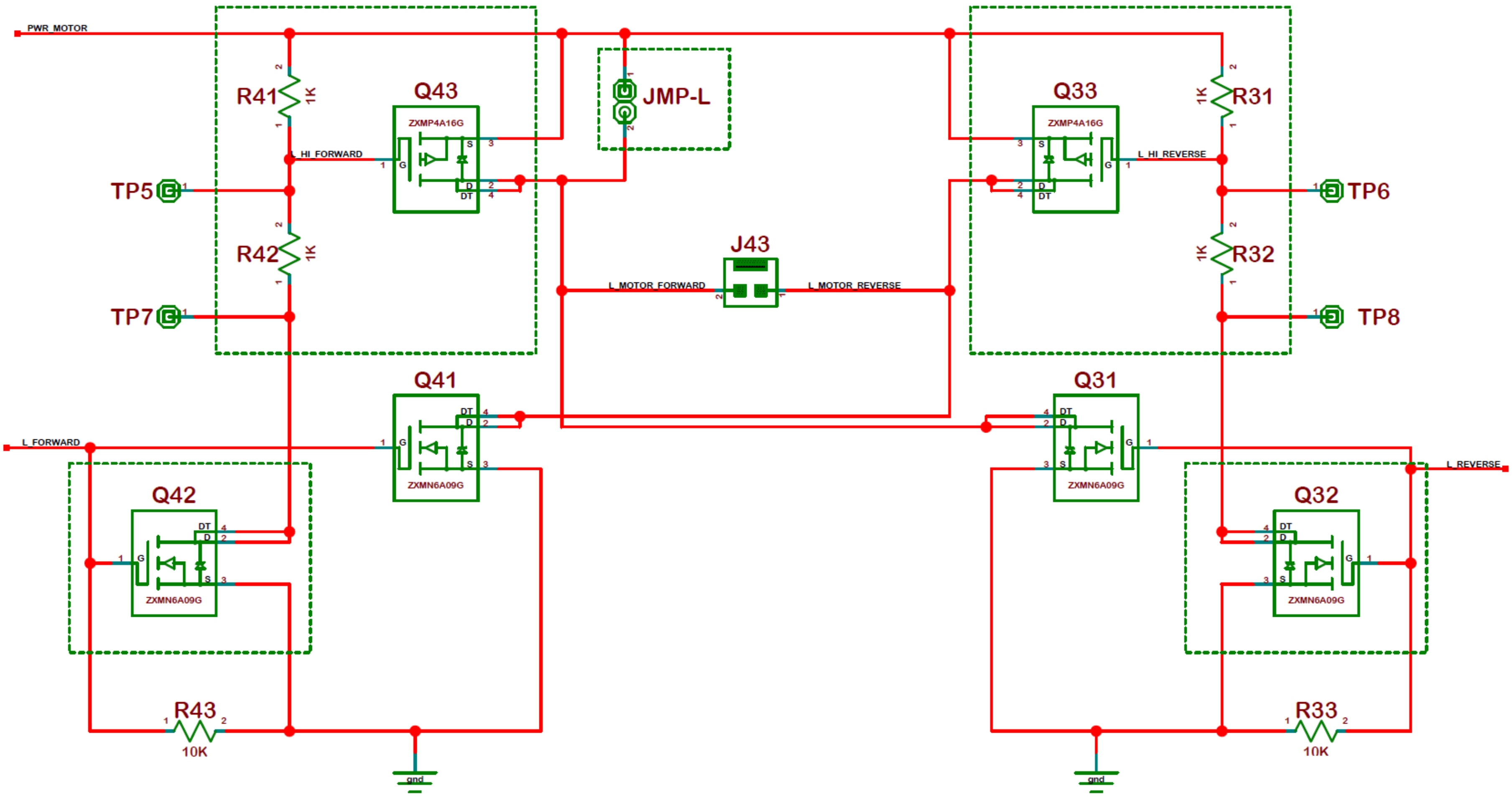

L1
CLS62NP-100NC
10UH
D1
PMEG3010BEP
SOD128
J2
PWR3_3
C9
1.0UF
U1
R18
21.5K
C8
27pF
SW1
OS102011MA1QN1
PWR6
D2
PMEG3010BEP
SOD128
BAT_IN
VIN
SW1
LT1930ES5
C3
10UF
C4
10UF
C6
10UF
C1
100UF
TP40
RAW_BATTERY
R16
10K
SHDN
FB
GND
0-0242-005-0003-00
J1
C7
10UF
C5
22UF
16V
C2
1.0UF
R17
13.3K
gnd

Schematics


Right Motor H-Bridge
PWR6
PWR9
JP1
PWR_MOTOR
R21
1K
R22
1K
Q23
ZXMP4A16G
R_HI_FORWARD
TP1
TP3
JMP-R
J21
R_MOTOR_FORWARD
R_MOTOR_REVERSE
Q13
ZXMP4A16G
R_HI_REVERSE
R11
1K
R12
1K
TP2
TP4
Q21
ZXMN6A09G
R_FORWARD
Q22
ZXMN6A09G
R23
10K
gnd
Q11
ZXMN6A09G
R_REVERSE
Q12
ZXMN6A09G
R13
10K
gnd

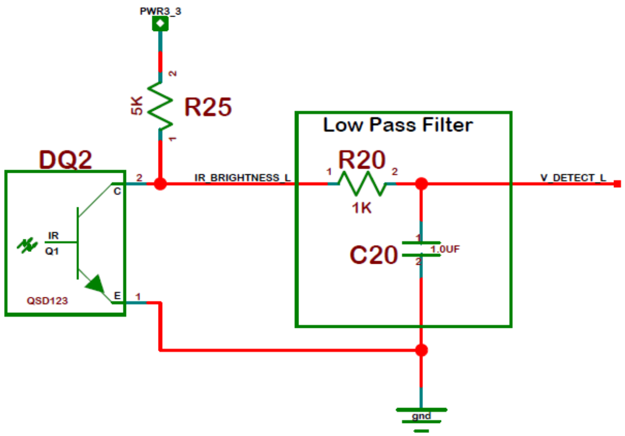
Schematics

Left Motor H-Bridge

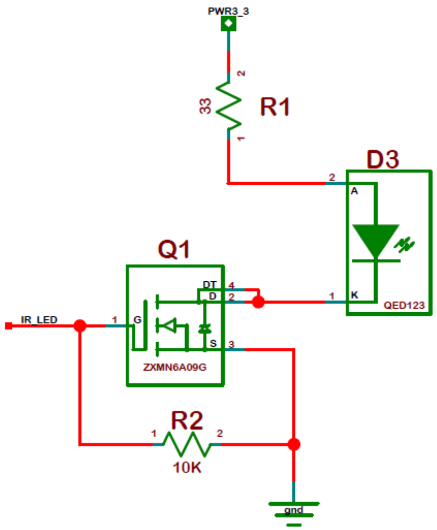


Schematics

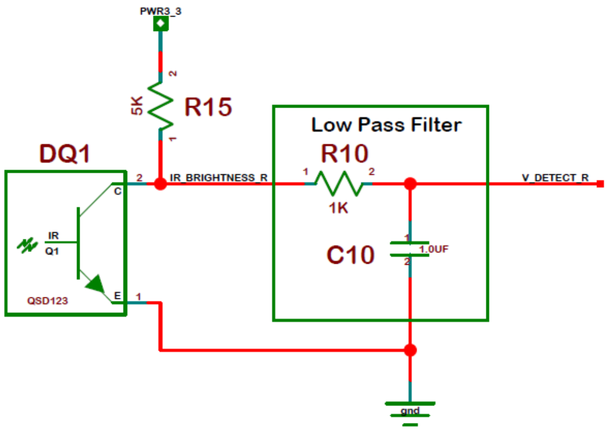
Left Side Line Detect



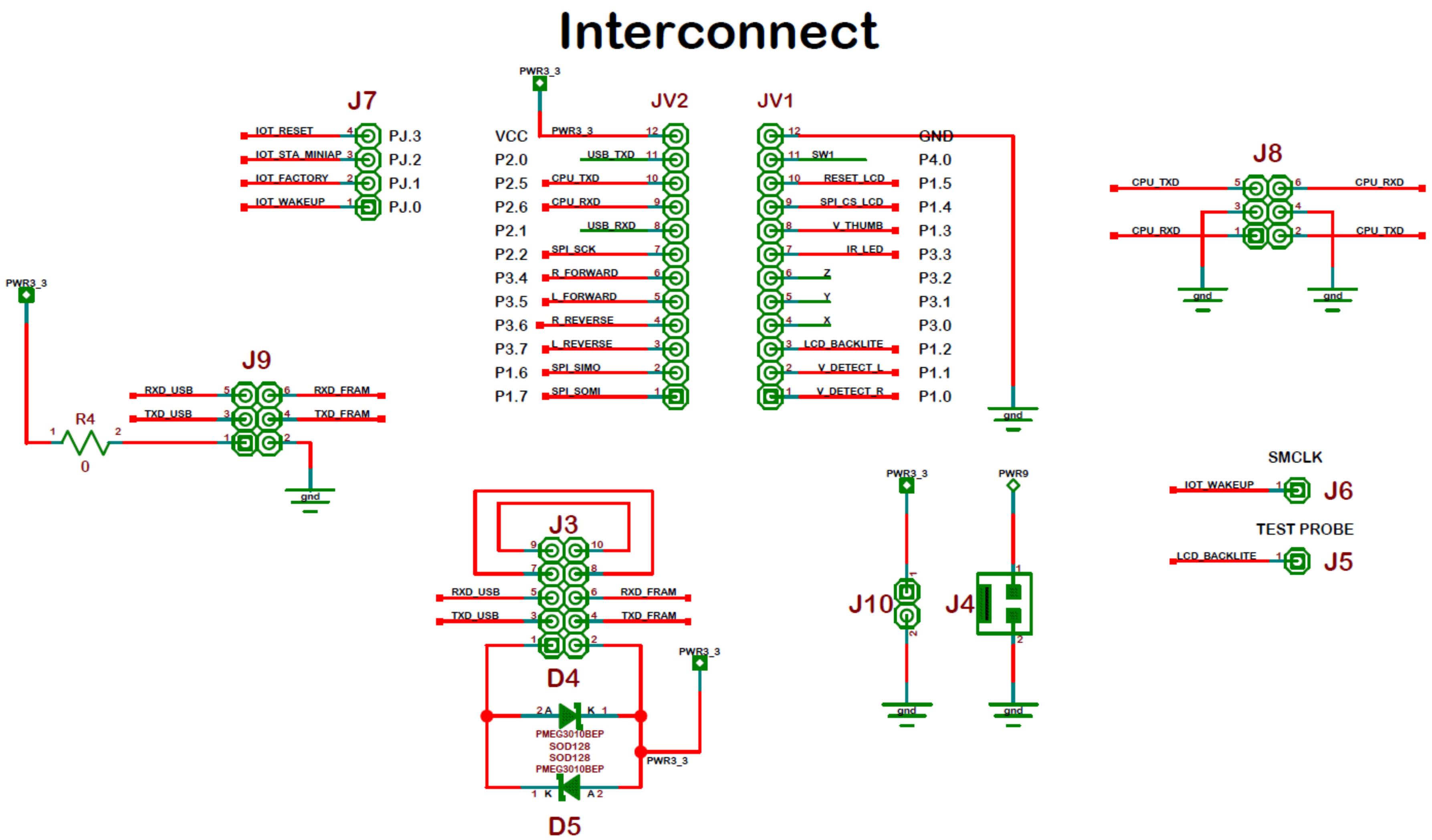
Center Emitter



Right Side Line Detect

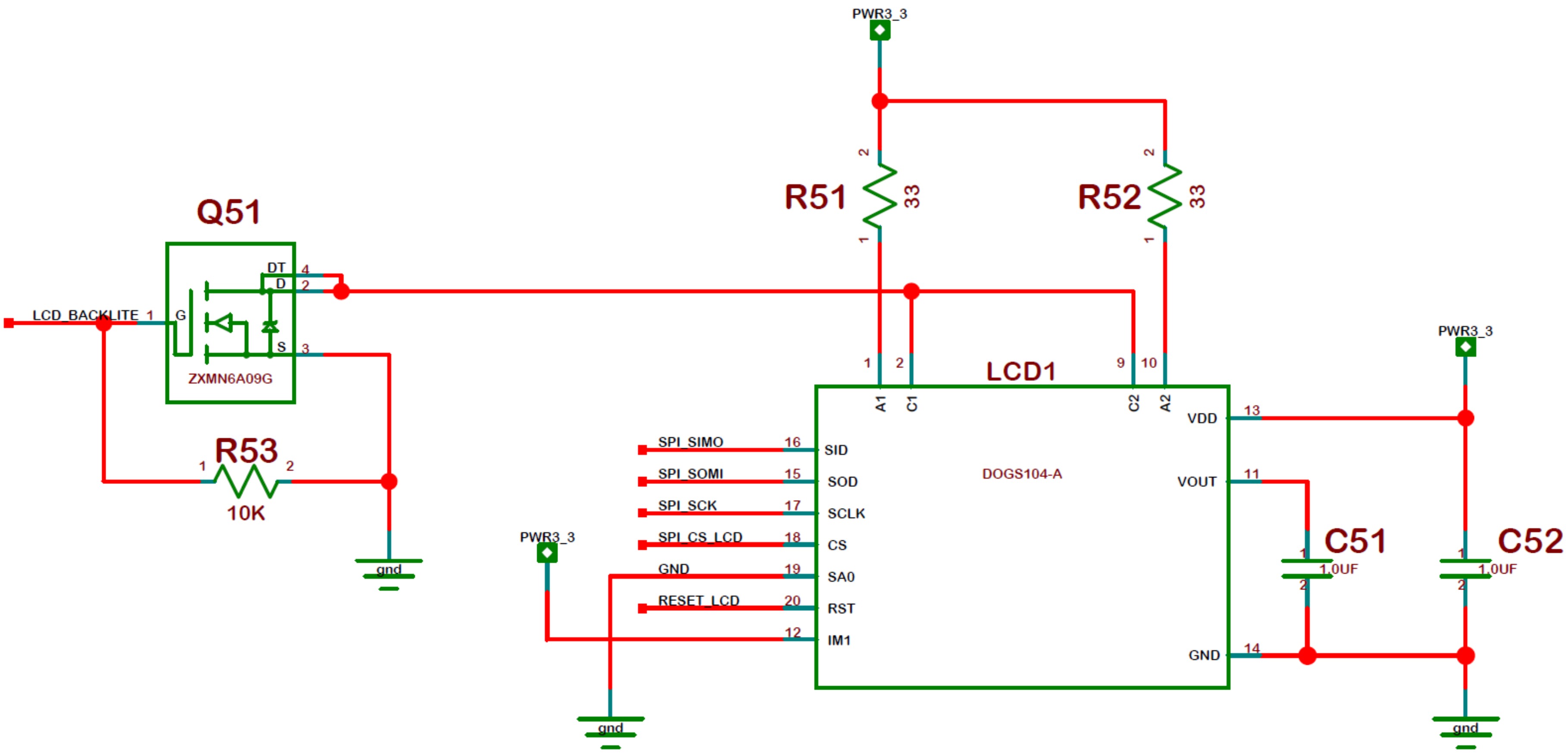


Schematics

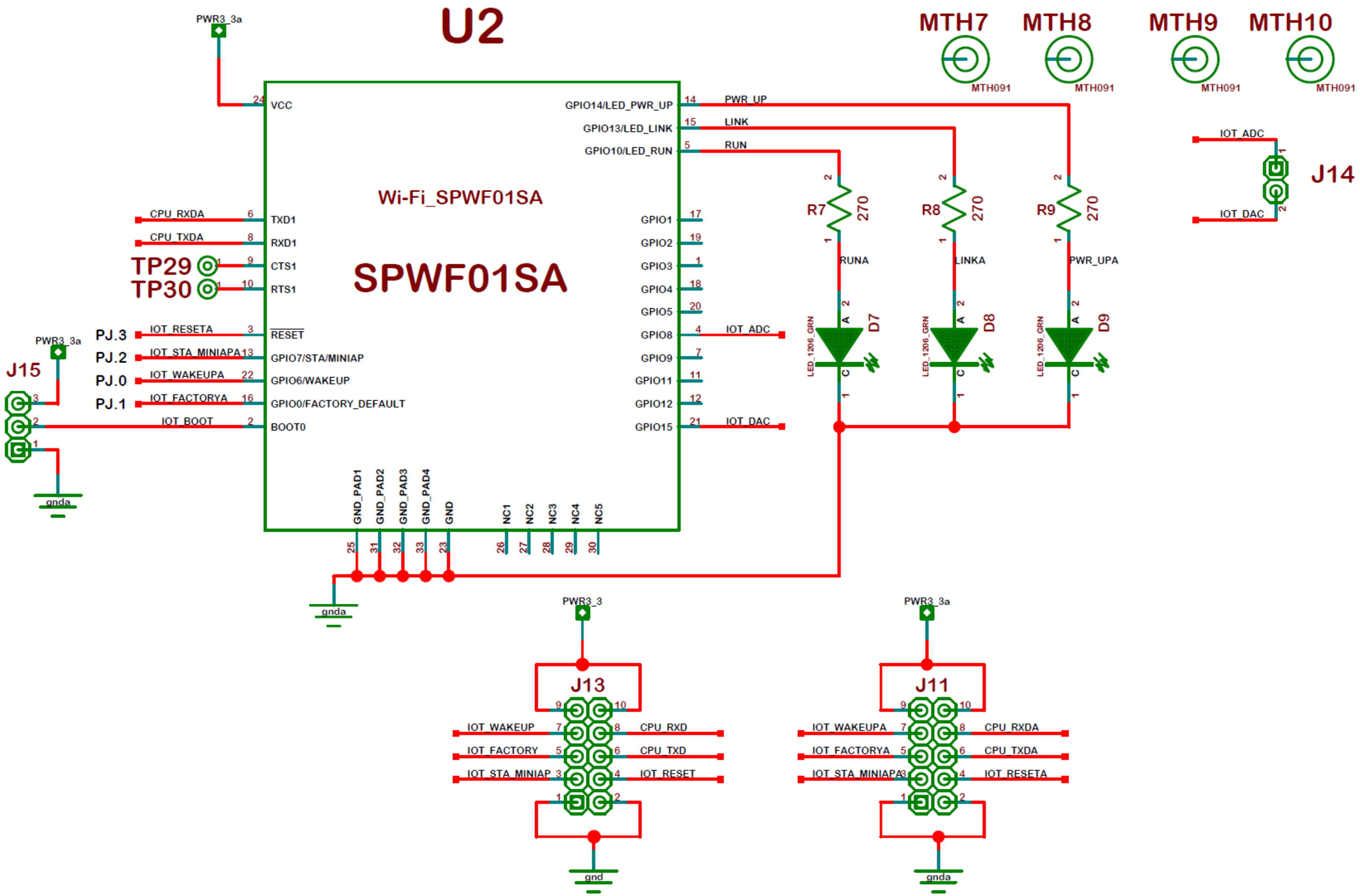

Interconnect
J7
IOT_RESET
IOT_STA_MINIAP
IOT_FACTORY
IOT_WAKEUP
PJ.3
PJ.2
PJ.1
PJ.0
PWR3_3
JV2
VCC
P2.0
P2.5
P2.6
P2.1
P2.2
P3.4
P3.5
P3.6
P3.7
P1.6
P1.7
USB_TXD
CPU_TXD
CPU_RXD
USB_RXD
SPI_SCK
R_FORWARD
L_FORWARD
R_REVERSE
L_REVERSE
SPI_SIMO
SPI_SOMI
JV1
GND
P4.0
P1.5
P1.4
P1.3
P3.3
P3.2
P3.1
P3.0
P1.2
P1.1
P1.0
SW1
RESET_LCD
SPI_CS_LCD
V_THUMB
IR_LED
Z
Y
X
LCD_BACKLITE
V_DETECT_L
V_DETECT_R
J8
CPU_TXD
CPU_RXD
gnd
J9
RXD_USB
TXD_USB
RXD_FRAM
TXD_FRAM
R4
0
J3
D4
D5
PMEG3010BEP
SOD128
SOD128
PMEG3010BEP
J10
J4
PWR9
SMCLK
J6
TEST PROBE
J5

Schematics

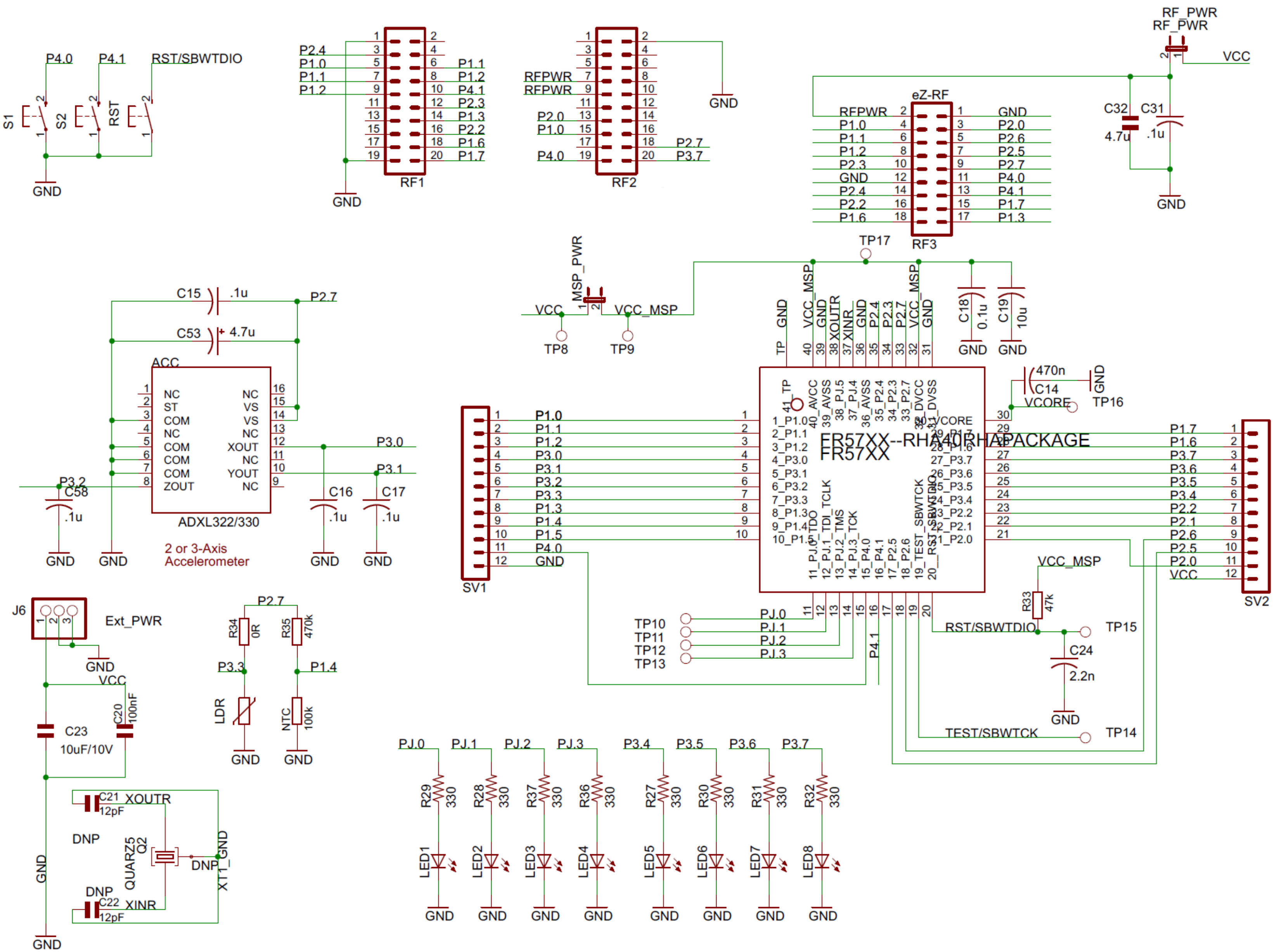
LCD



Schematics


U2
PWR3_3a
VCC
Wi-Fi_SPWF01SA
SPWF01SA
GPIO14/LED_PWR_UP
GPIO13/LED_LINK
GPIO10/LED_RUN
PWR_UP
LINK
RUN
CPU_RXDA
CPU_TXDA
TXD1
RXD1
CTS1
RTS1
TP29
TP30
PJ.3
PJ.2
PJ.0
PJ.1
IOT_RESETA
IOT_STA_MINIAPA
IOT_WAKEUPA
IOT_FACTORYA
IOT_BOOT
RESET
GPIO7/STA/MINIAP
GPIO6/WAKEUP
GPIO0/FACTORY_DEFAULT
BOOT0
GPIO1
GPIO2
GPIO3
GPIO4
GPIO5
GPIO8
GPIO9
GPIO11
GPIO12
GPIO15
IOT_ADC
IOT_DAC
J15
gnda
GND_PAD1
GND_PAD2
GND_PAD3
GND_PAD4
GND
NC1
NC2
NC3
NC4
NC5
MTH7
MTH8
MTH9
MTH10
MTH091
J14
R7
R8
R9
270
RUNA
LINKA
PWR_UPA
D7
D8
D9
LED_1206_GRN
PWR3_3
J13
J11
IOT_WAKEUP
IOT_FACTORY
IOT_STA_MINIAP
CPU_RXD
CPU_TXD
IOT_RESET
gnd

Schematics


S1
S2
RST
P4.0
P4.1
RST/SBWTDIO
GND
RF1
RF2
eZ-RF
RF3
RF_PWR
VCC
C32
4.7u
C31
.1u
TP17
MSP_PWR
VCC_MSP
TP8
TP9
C15
C53
P2.7
ACC
ADXL322/330
2 or 3-Axis
Accelerometer
C58
C16
C17
P3.0
P3.1
P3.2
SV1
SV2
FR57XX--RHA40RHAPACKAGE
FR57XX
C18
0.1u
C19
10u
C14
470n
VCORE
TP16
VCC_MSP
R33
47k
RST/SBWTDIO
TP15
C24
2.2n
TEST/SBWTCK
TP14
TP10
TP11
TP12
TP13
PJ.0
PJ.1
PJ.2
PJ.3
J6
Ext_PWR
C23
10uF/10V
C20
100nF
R34
0R
R35
470k
P3.3
P1.4
LDR
NTC
100k
C21
12pF
XOUTR
DNP
QUARZ5
Q2
XT1_
C22
12pF
XINR
P3.4
P3.5
P3.6
P3.7
R29
R28
R37
R36
R27
R30
R31
R32
330
LED1
LED2
LED3
LED4
LED5
LED6
LED7
LED8

Schematics

- Project Template –
- Write-up Expectations –