Life-Watch

Wearable Medical Device

John Alcala – EE
William Toledo – EE
Josue Ortiz – EE
Carter Lankes - EE

UCF | College of Engineering and Computer Science
UNIVERSITY OF CENTRAL FLORIDA

Motivation

- Hospital miscommunication and errors 2,000 lives and $1.7 billion, Up to 80% of serious medical errors due to miscommunication while transferring patients (Source: Joint Commission)
- Patients being confused for other patients
- Patients being sent to wrong areas of the hospital
- Worst case scenario, patients having wrongful surgeries

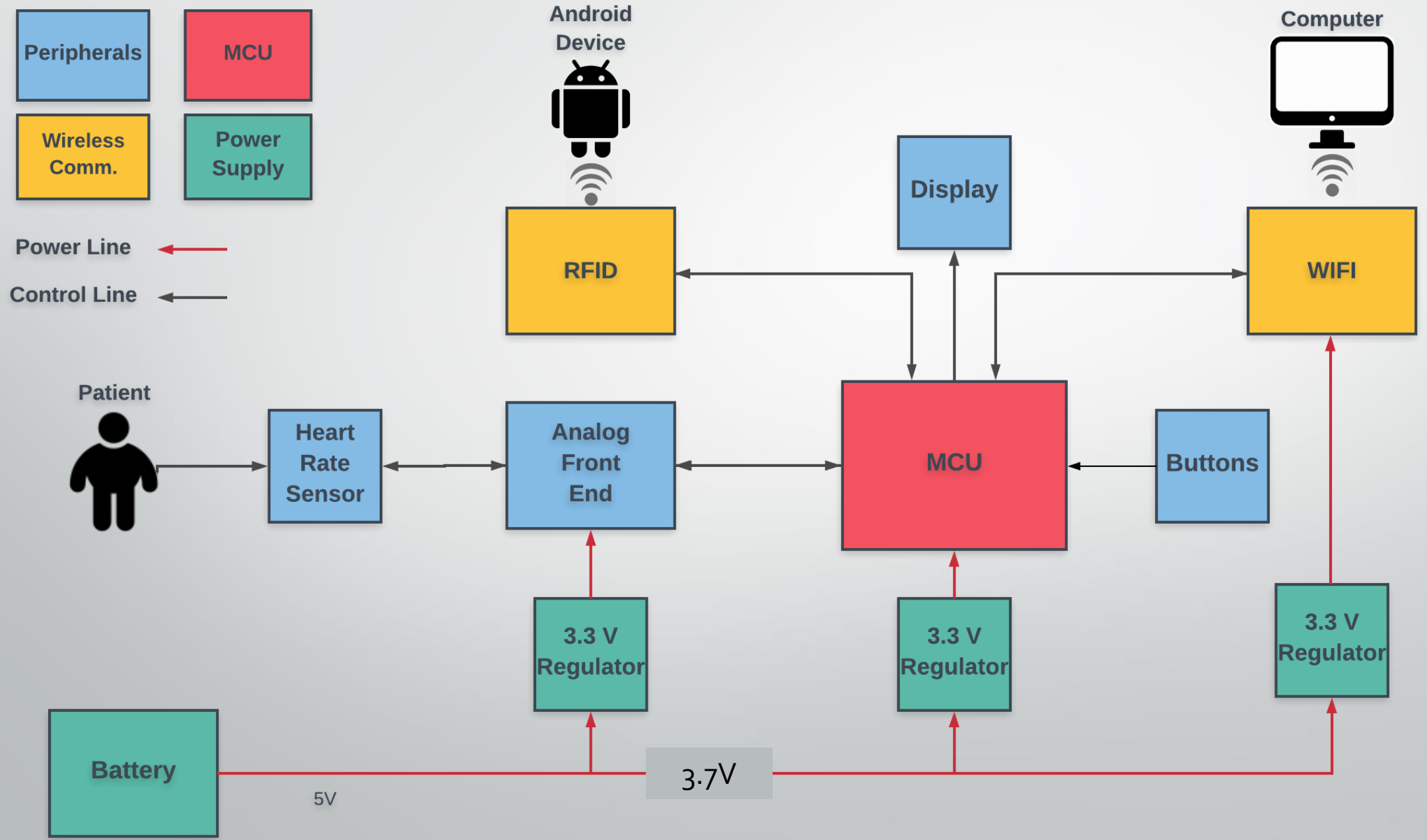
Solution

- The use of modern integrated circuits to provide a cost-effective way to reduce cases of human error
  - Identify patients wirelessly
  - Track patient within hospital
  - Monitor heart rate
  - Provide emergency response system
  - Battery powered, wrist-worn device

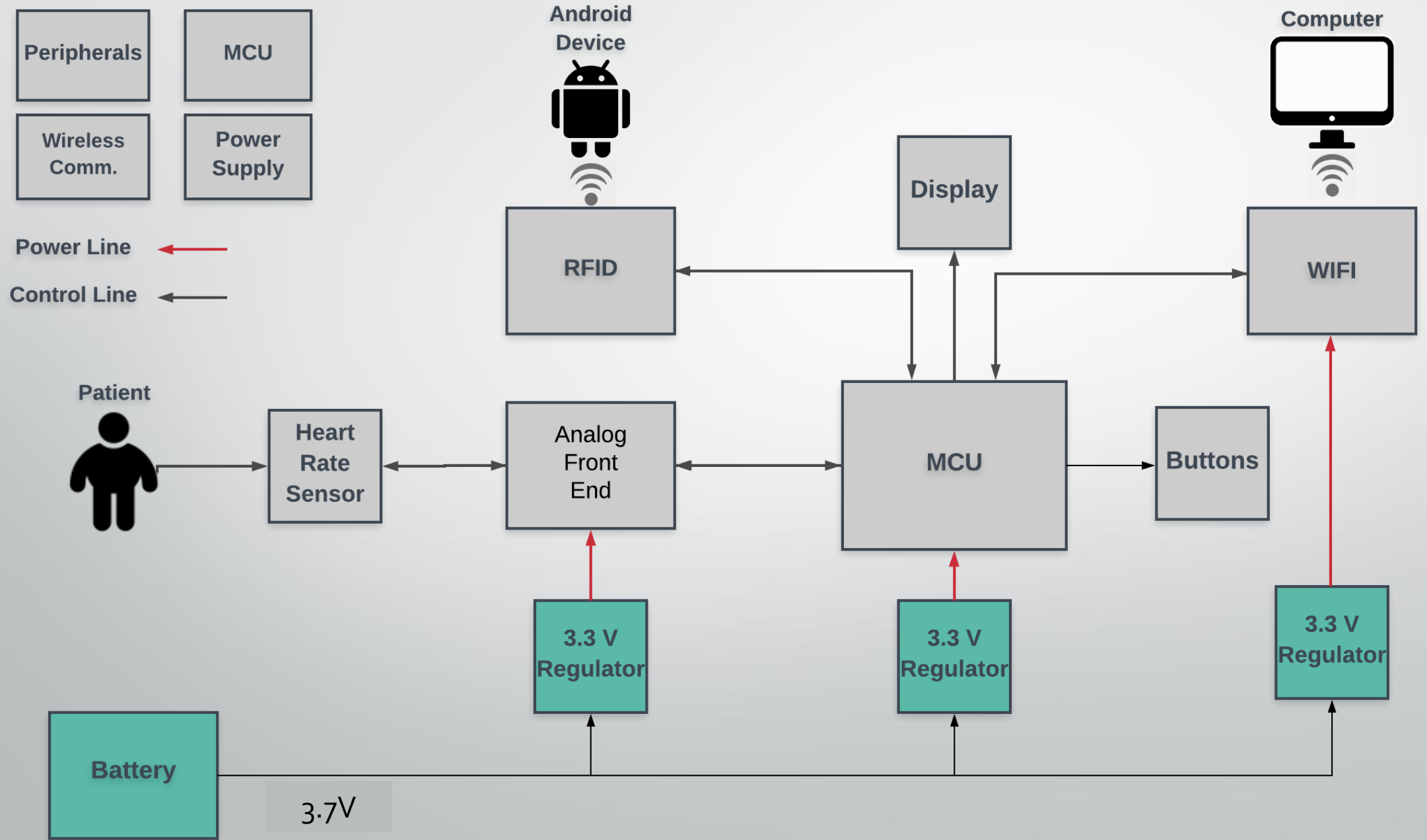
Engineering Specifications

- 100x100 mm^2 PCB Area
- Weigh less than 300 grams
- 5 hour Battery Life
- Within 5m Location Accuracy of the patient
- Cost less than $250

Block Diagram



Power Supply



Voltage Regulators
TPS63036

Includes:

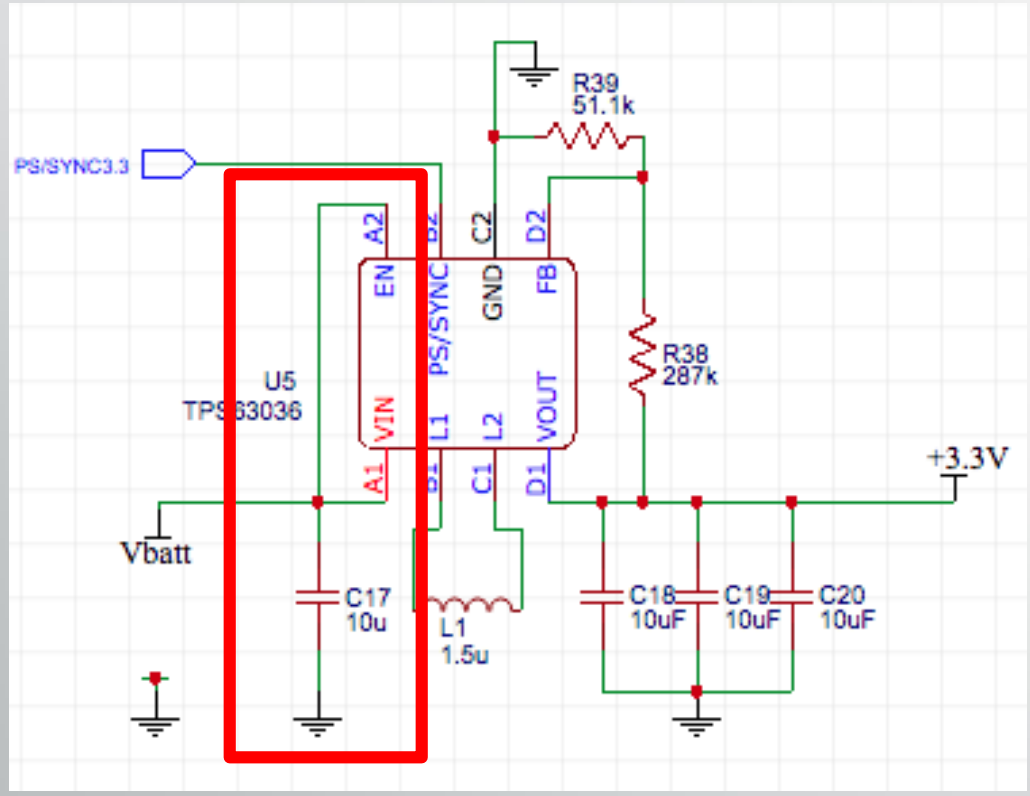
- Up to 94% efficiency
- Power save mode
- Overtemperature protection
- Very compact

Spec	TPS63036
Input voltage	1.8V - 5.5V
Output voltage	1.2V - 5.5V
Size	1.854 mm × 1.076 mm
Cost	$1.71

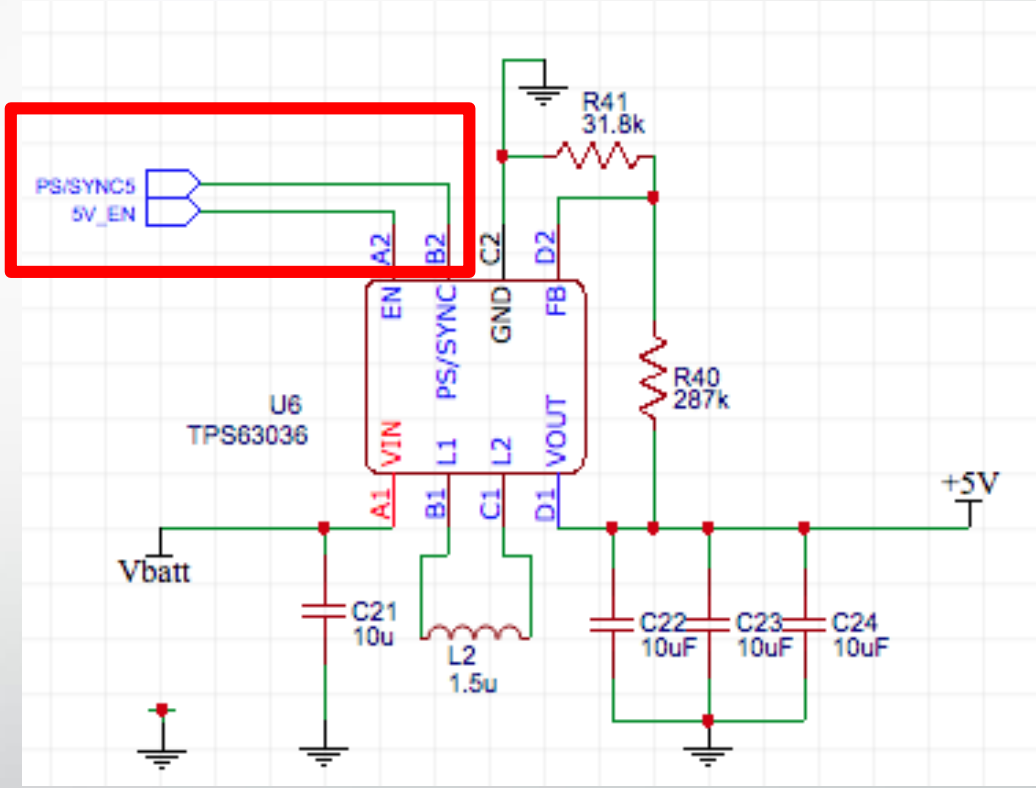
Texas Instruments

Voltage Regulators TPS63036 Schematic

3.7V to 3.3V



3.7V to 5V



$$R1 = R2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right)$$

Battery

EBL 18650 3.7V Li-ion

- Mainly for testing purposes
- Overkill, more mAh than necessary
- Will be replaced with smaller battery

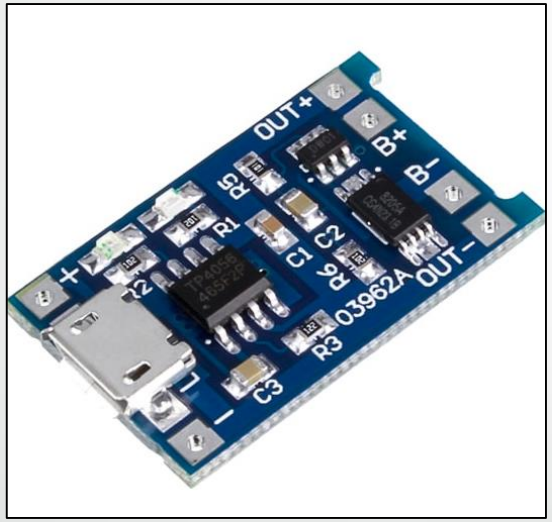
Spec	EBL 18650 3.7V Li-ion
Capacity	3000 mAh
Size	3 x 1.6 x 1.8 inches
Cost	$3.25
Life	1200 recharges

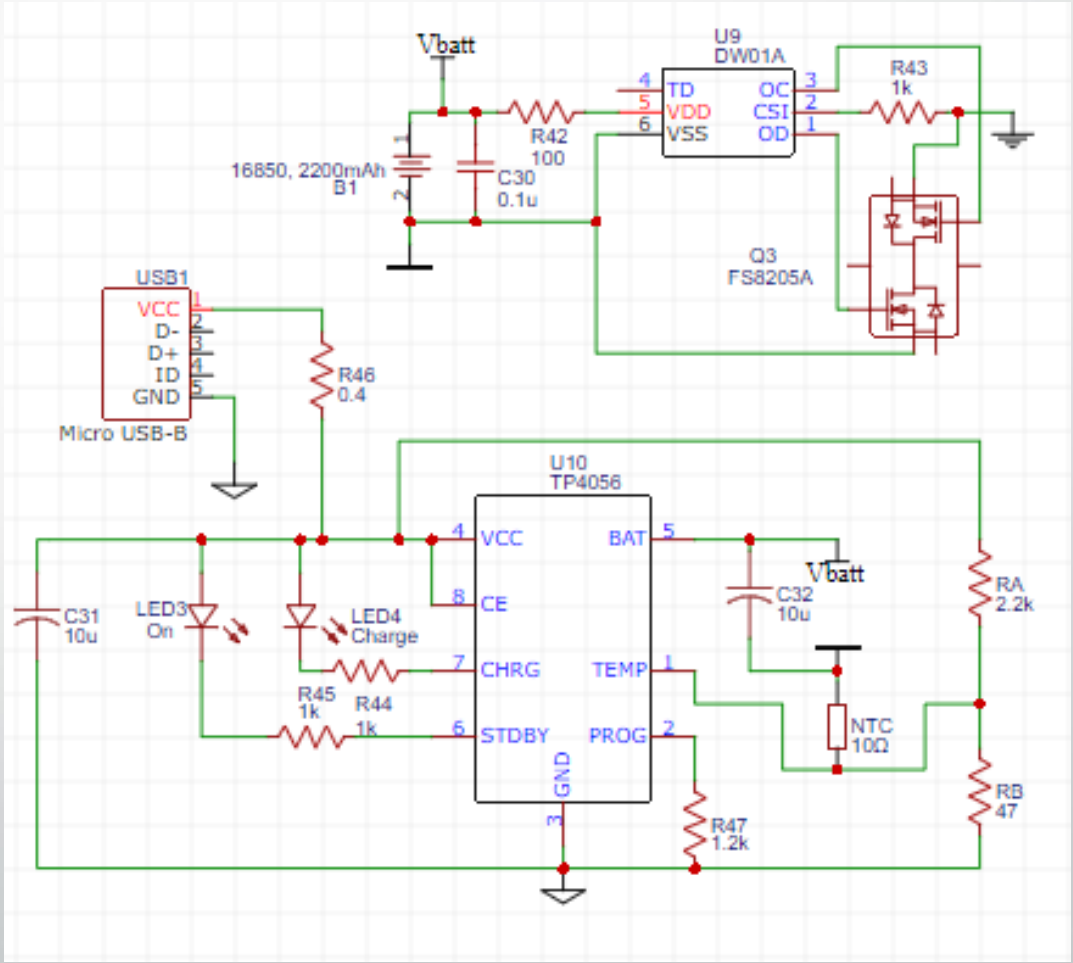
EBL

Battery and Charging

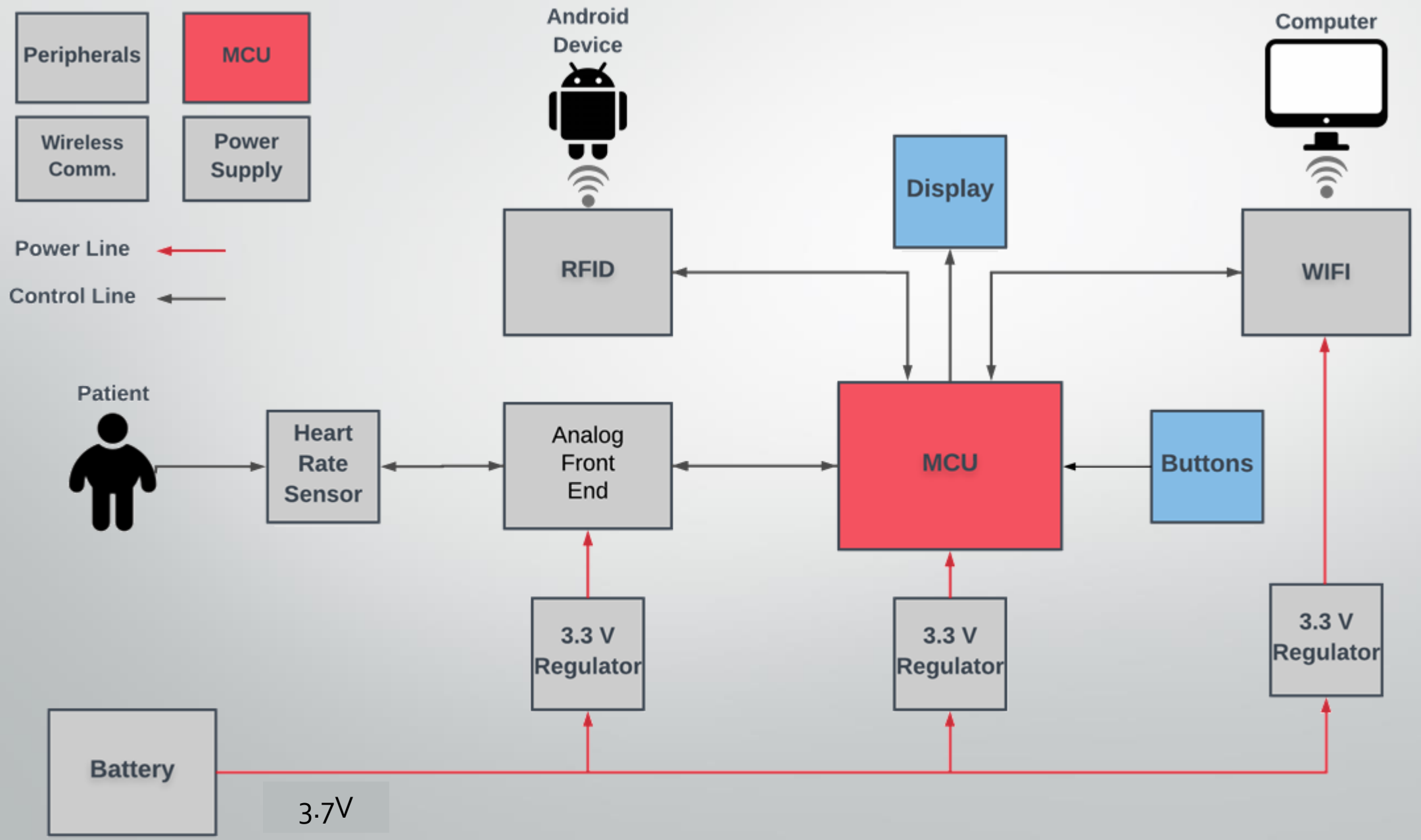
TP4056 Lithium Battery Charger and Protection Module, $1.25

- TP4056
  - CC/CV charging method
  - Temperature protection
  - Status LEDs
  - Programable Charge Current, 1A
- DW01A
  - OCP, 4.3V +/- 50mV
  - ODP, 2.4V +/- 100mV
  - OIP, 150





MCU


Peripherals
MCU
Wireless Comm.
Power Supply
Power Line
Control Line
Android Device
Computer
Display
RFID
WIFI
Patient
Heart Rate Sensor
Analog Front End
MCU
Buttons
3.3 V Regulator
3.3 V Regulator
3.3 V Regulator
Battery
3.7V

Communication Protocols

- *I2C*
  - ✓ *2 Wires, Simple*
  - X *Limited Addresses*
  - X *Slower, Pull-Up Resistors*
- *SPI*
  - ✓ *Unlimited Devices, Fast*
  - X *Enable pin per device; more I/O pins required*

Main Components	Serial Communication
NFC	I2C
WIFI	I2C or SPI
Analog Front End	SPI
Display	4 Pin Communication

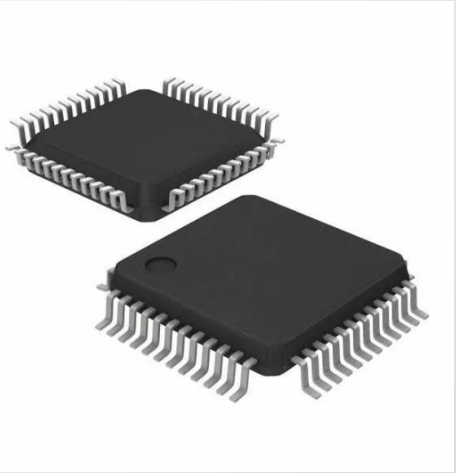
Microcontroller

MSP430FR4133

Main Requirements

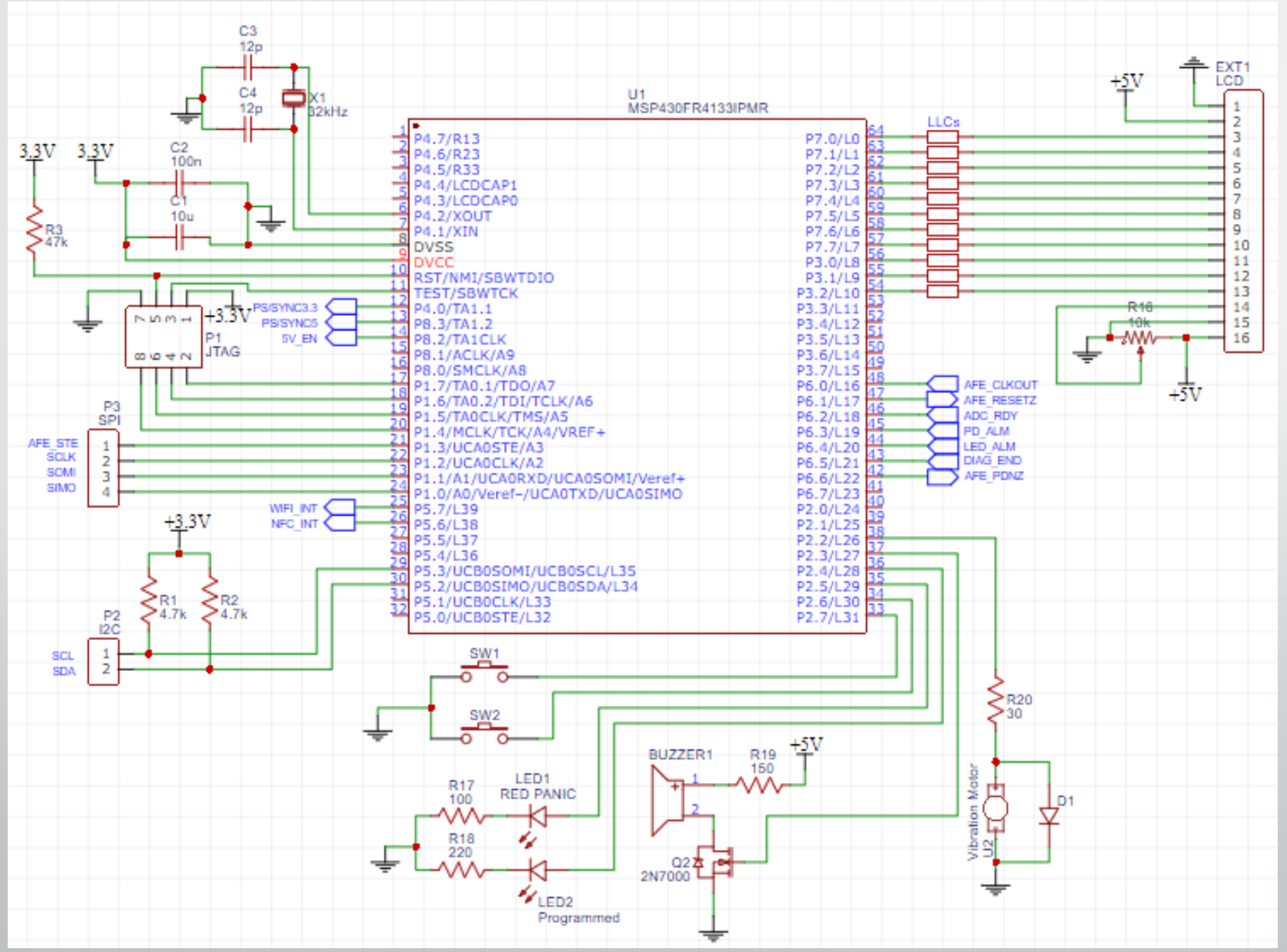
- *Low Power*
- *GPIO*
- *Serial Communications*
- *Helpful IDE, CCS*
- *Community*

Spec	MSP430FR4133	ATmega328PB
Current	**0.5mA**	**1.4mA**
Idle Mode	0.77u	2.1uA
Low Power	**80uA**	**2.1uA**
Size	12.2x12.2mm^2	9x9mm^2
GPIO	**60**	**27**
Cost	$1.21	$1.61
Comm. Ports	1xI2C, 1xSPI	2xI2C , 2xSPI
Memory	16KB	32KB

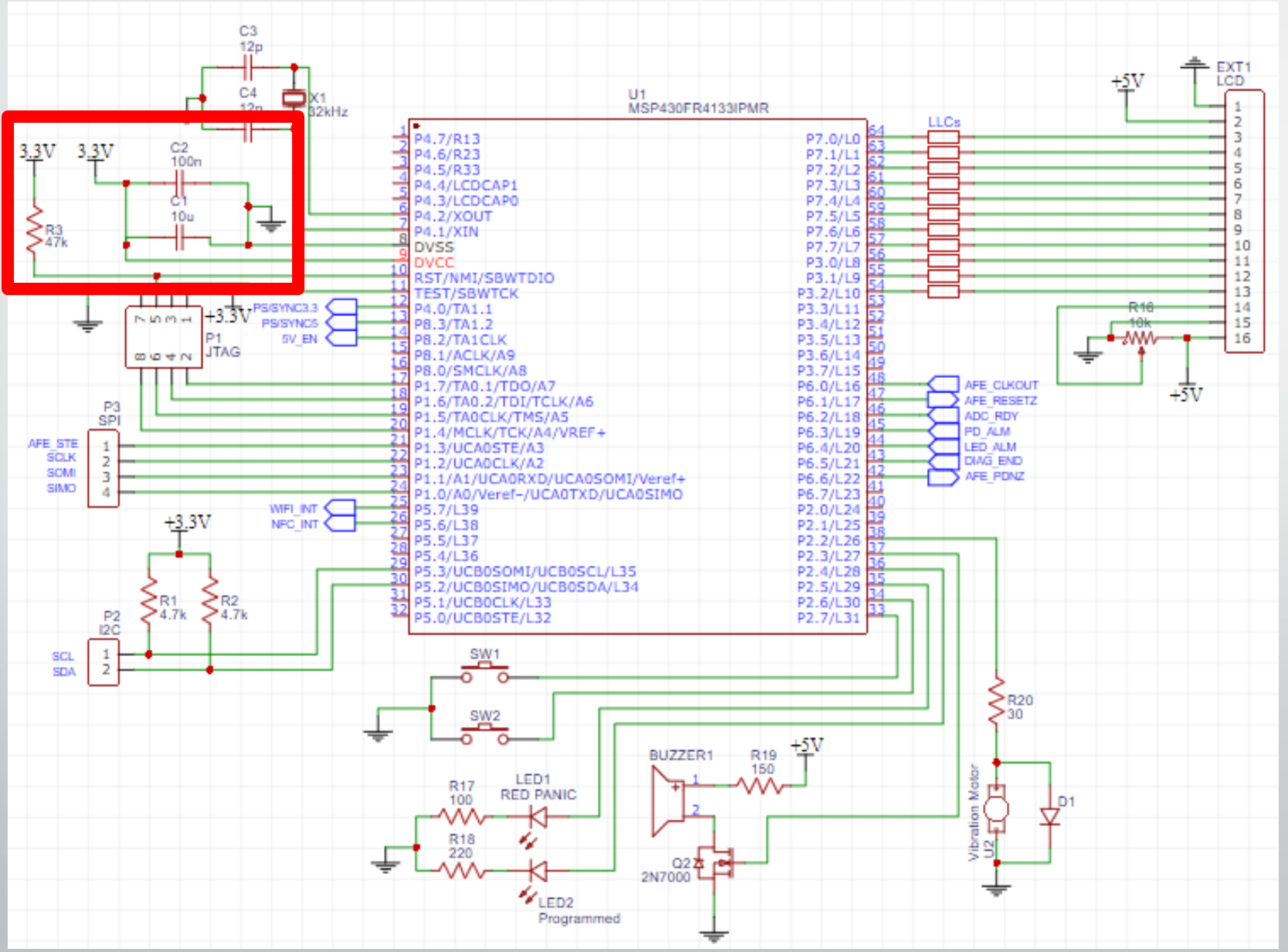


Texas Instruments

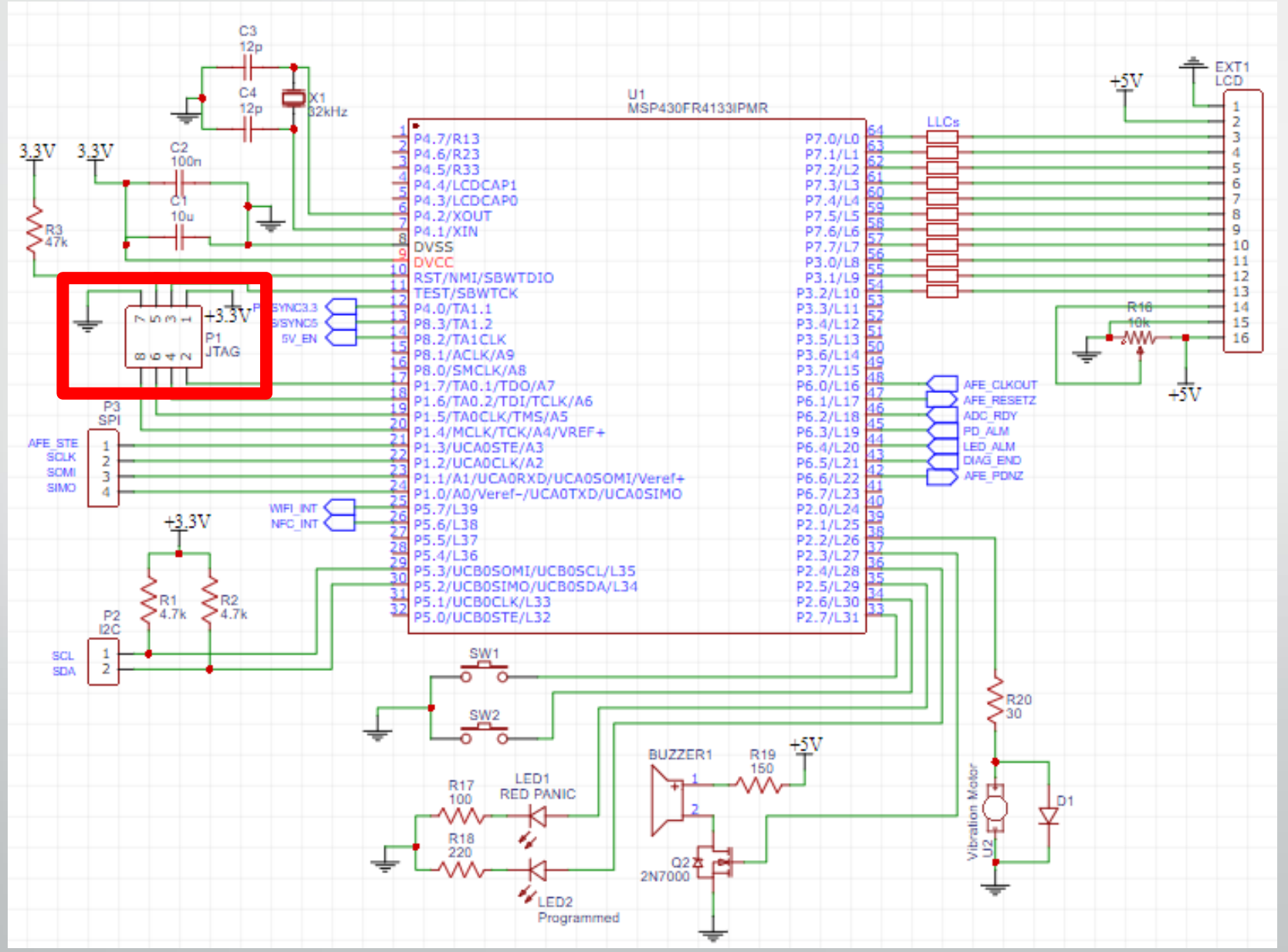
Microcontroller Schematic



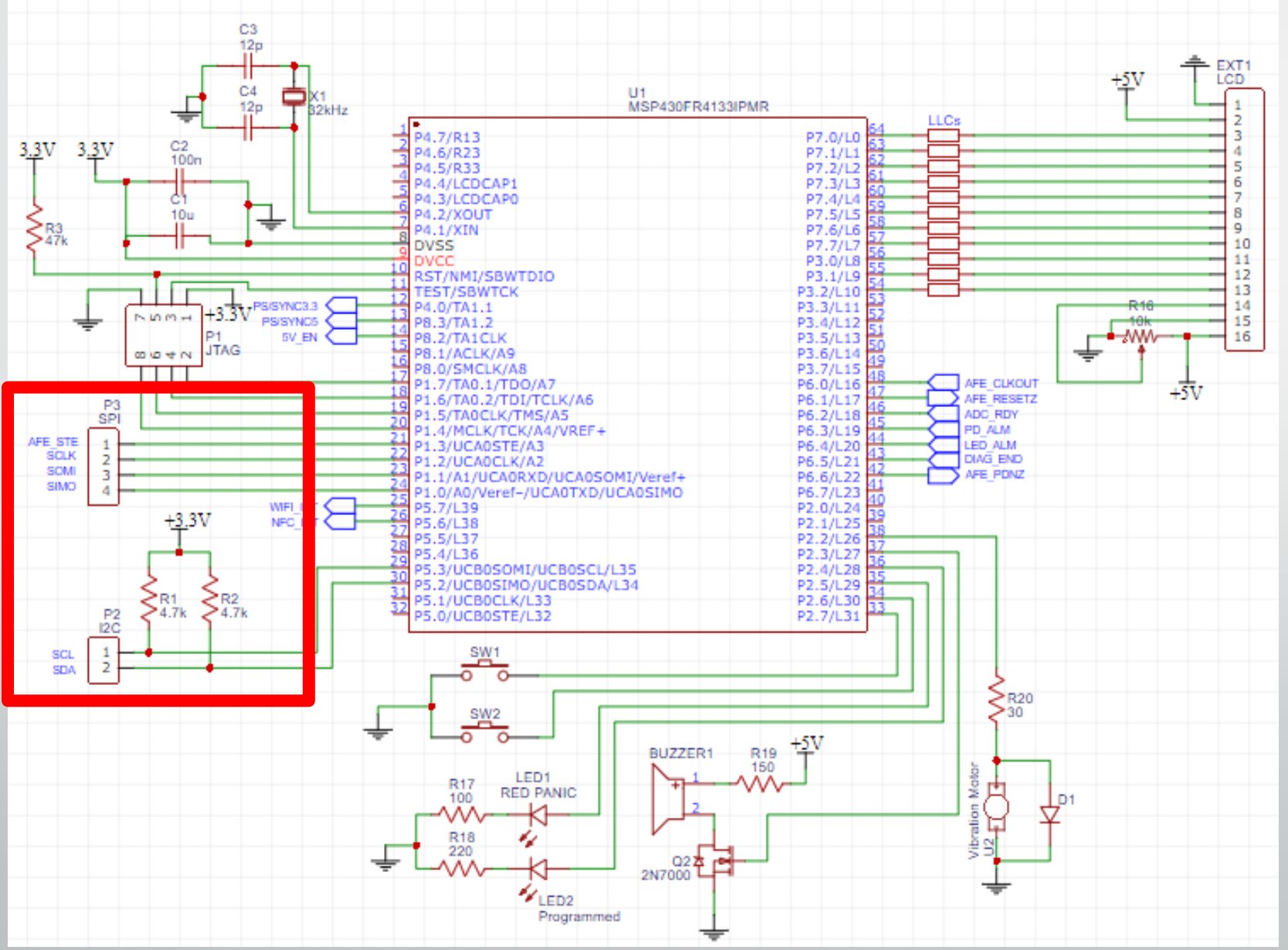
Microcontroller Schematic



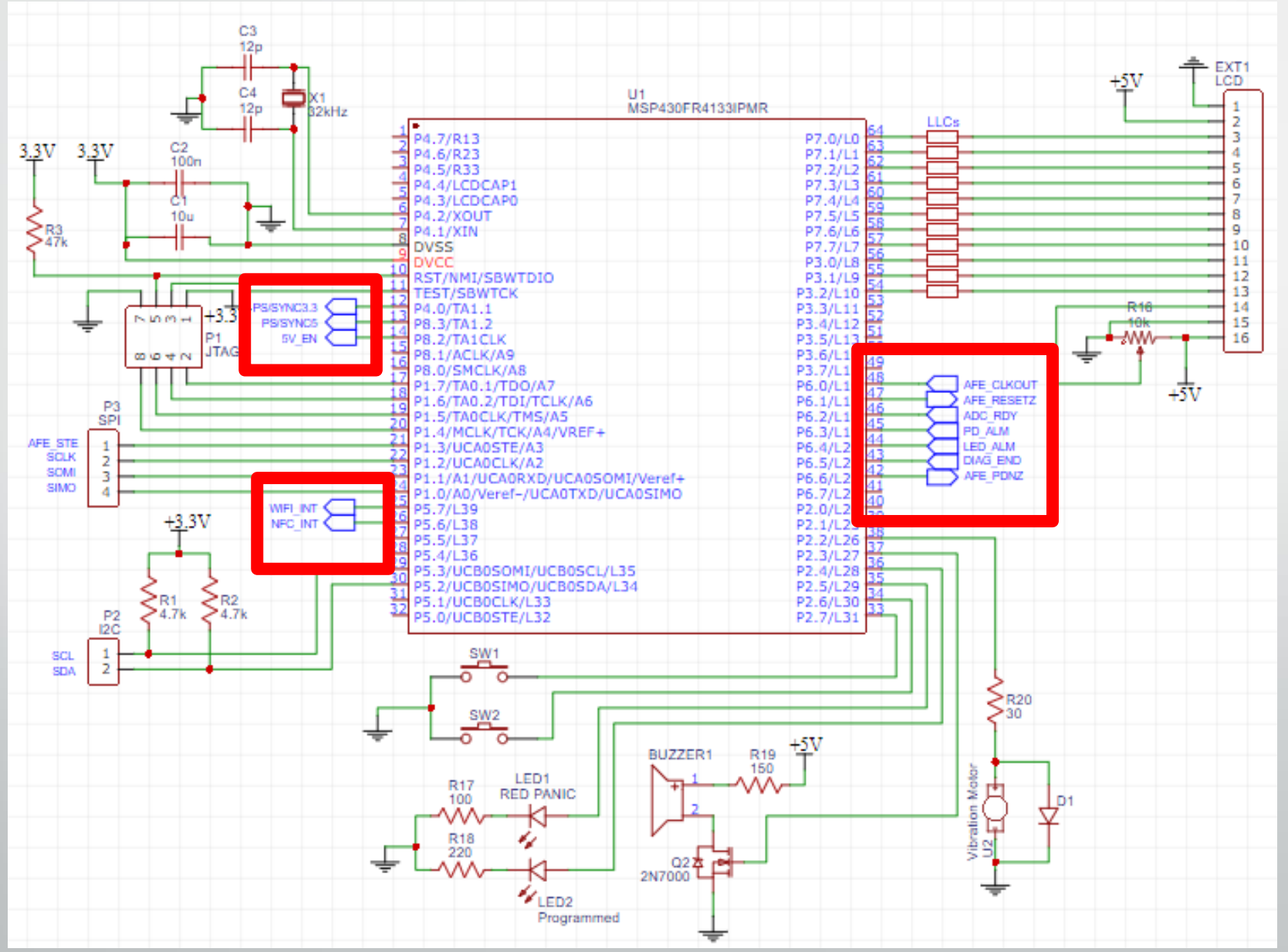
Microcontroller Schematic



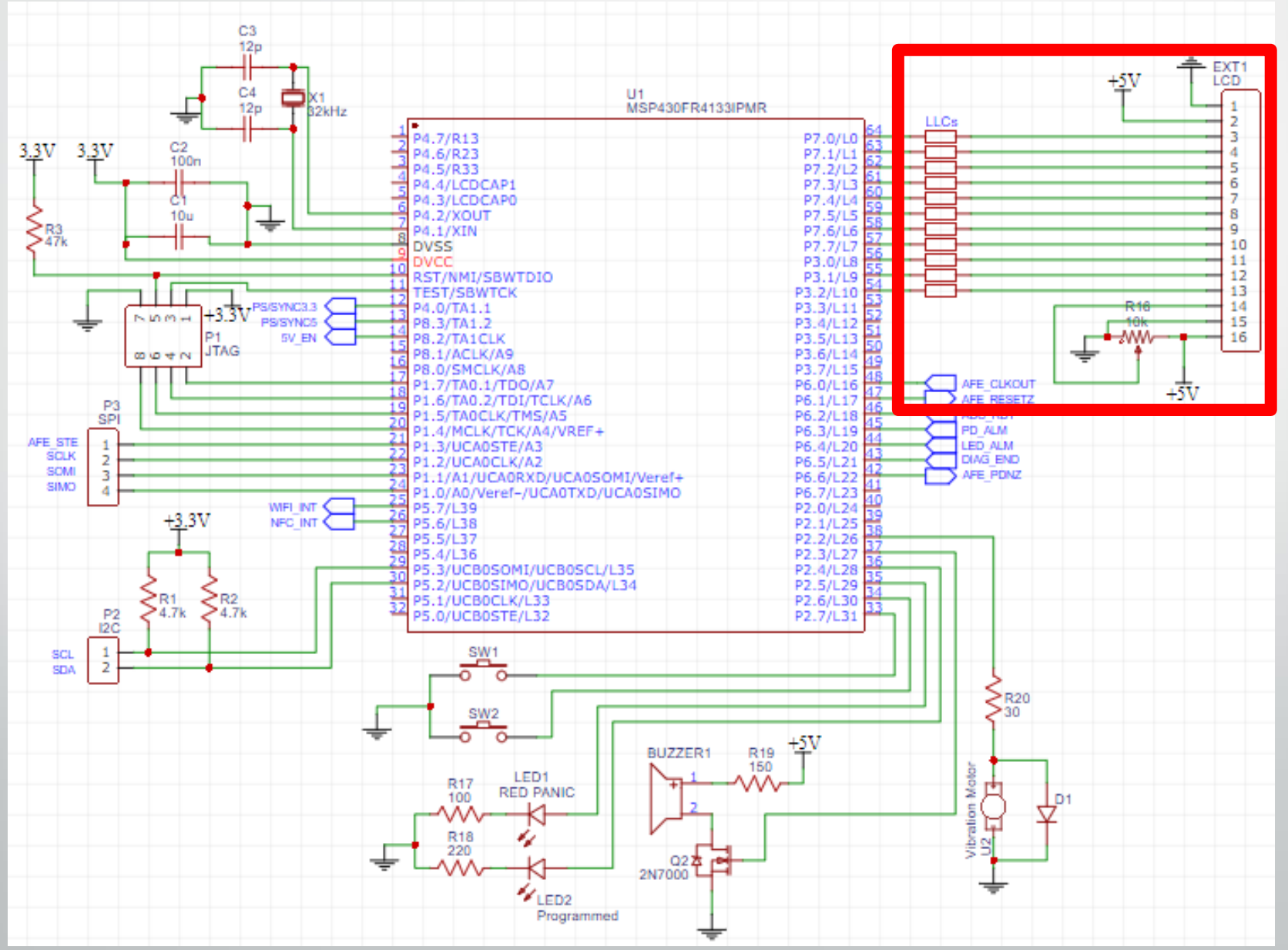
Microcontroller Schematic



Microcontroller Schematic



Microcontroller Schematic



NHD-C0216AZ-FSW-GBW

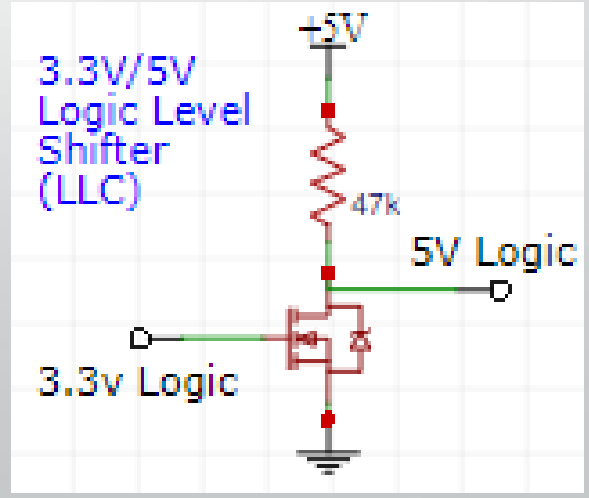
LCD Display

Main Requirements

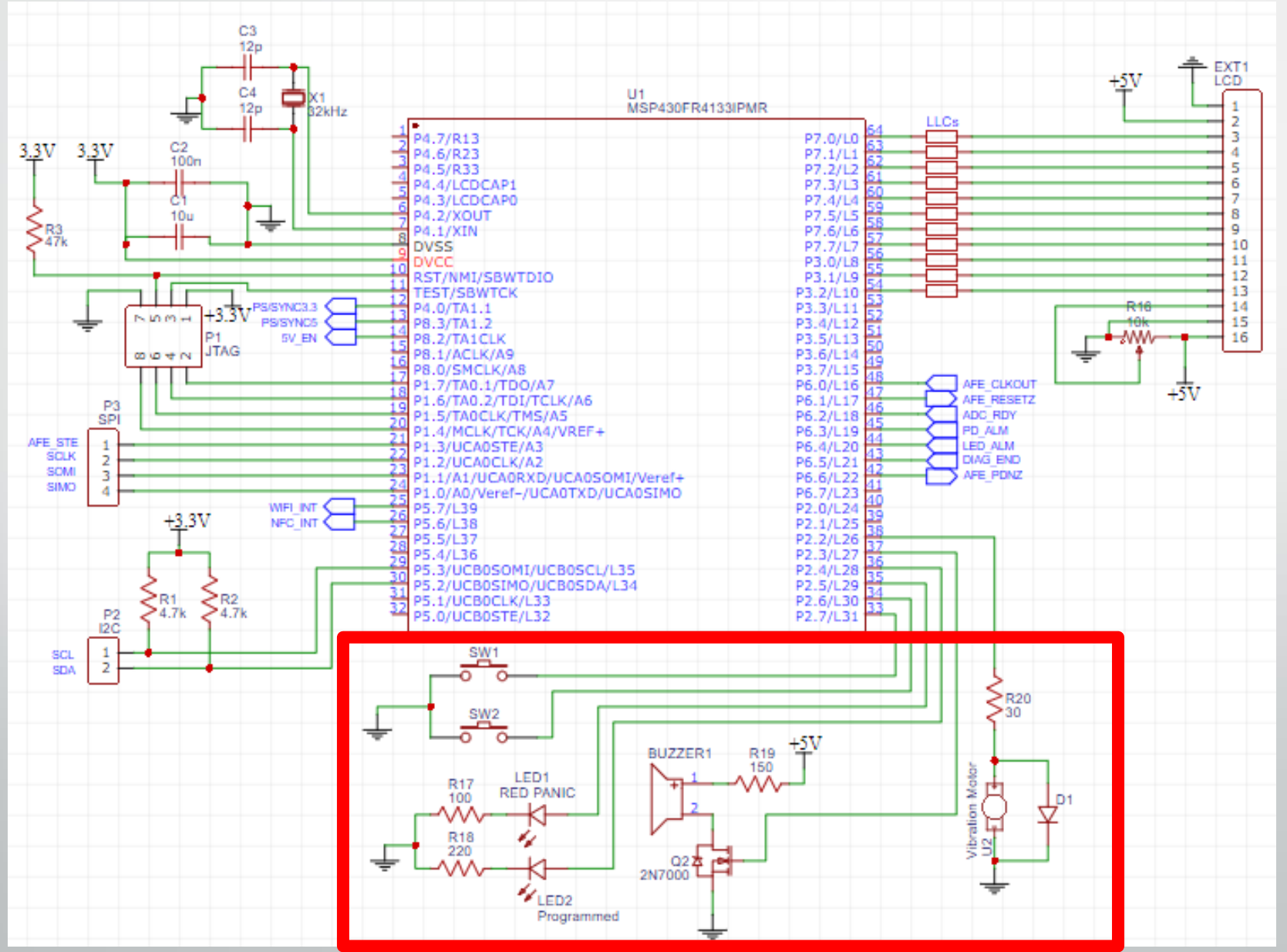
- *Small Size*
- *Use Few GPIO*
- *Adjustable Backlight*

Logic Level Shifter

Spec	NHD-C0216AZ-FSW-GBW
Characters	**16x2**
Resolution	5x10 pixels
Display	**49.4x12.3mm^2**
Total Size	54.6x25.3mm^2
GPIO	**4 or 8**
Cost	$10.11
Logic	5V

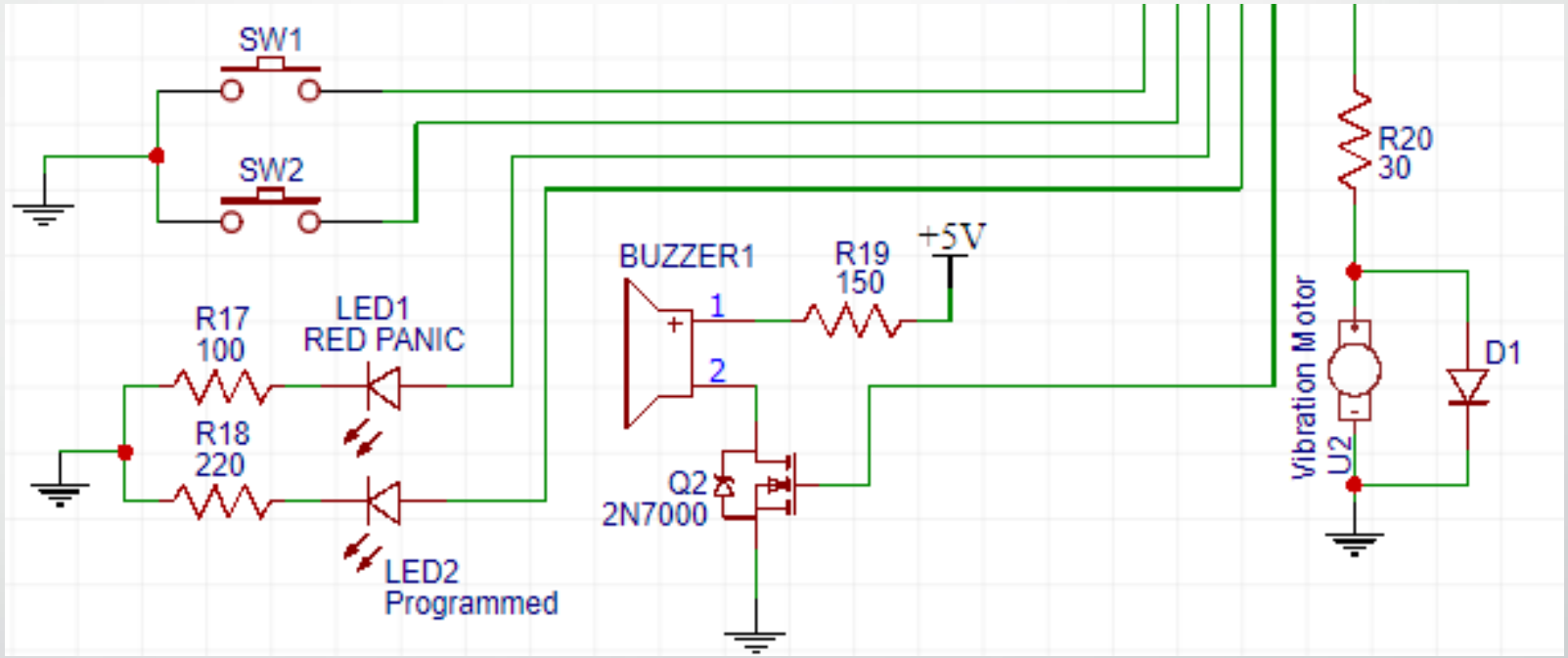


Microcontroller Schematic

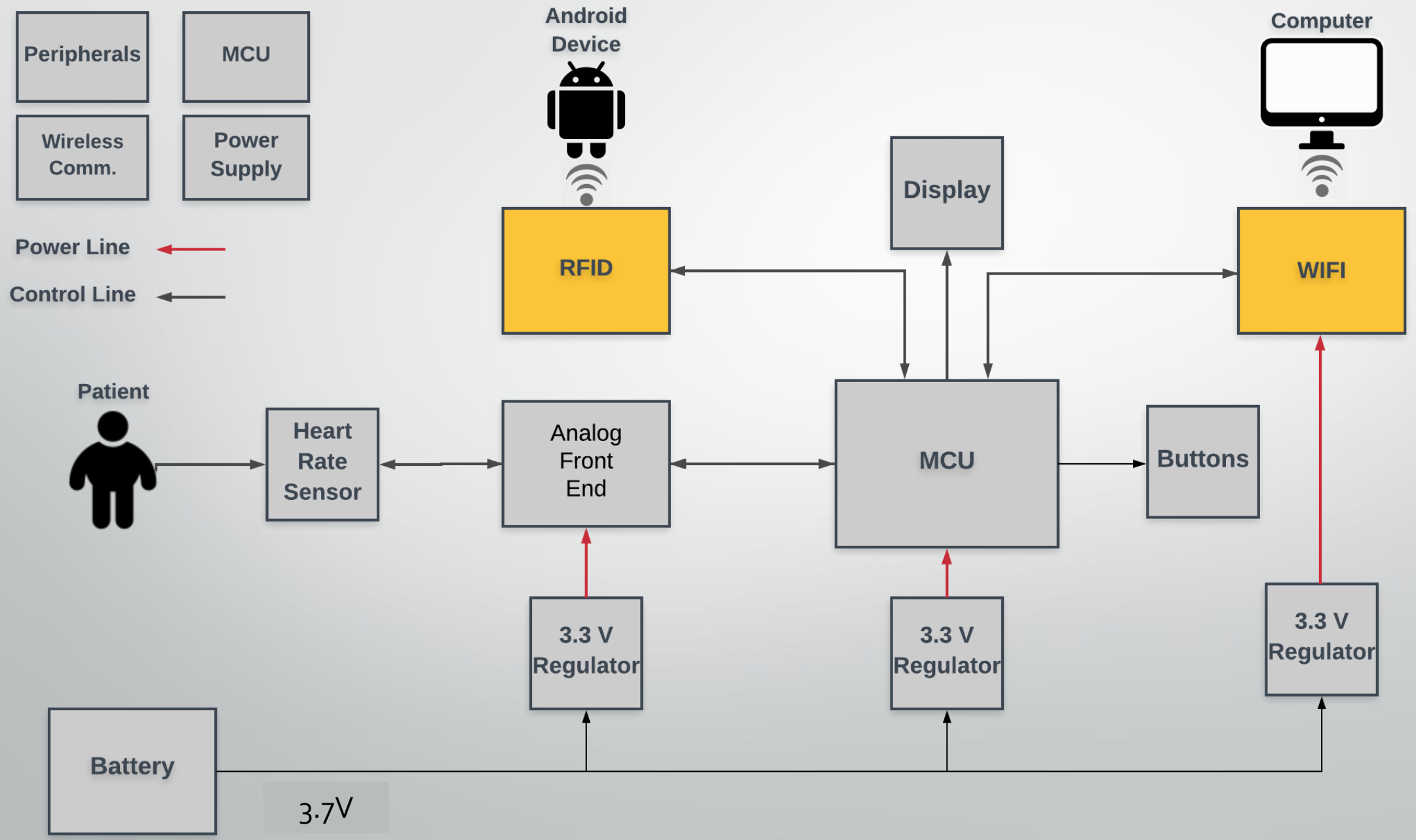


Emergency Response

- *Two Buttons, Long Press*
- *Turn on alarm and vibration motor*
- *Sends distress signal and location to server*
- *Activate Constant Wifi Tracking*



Wireless Communication

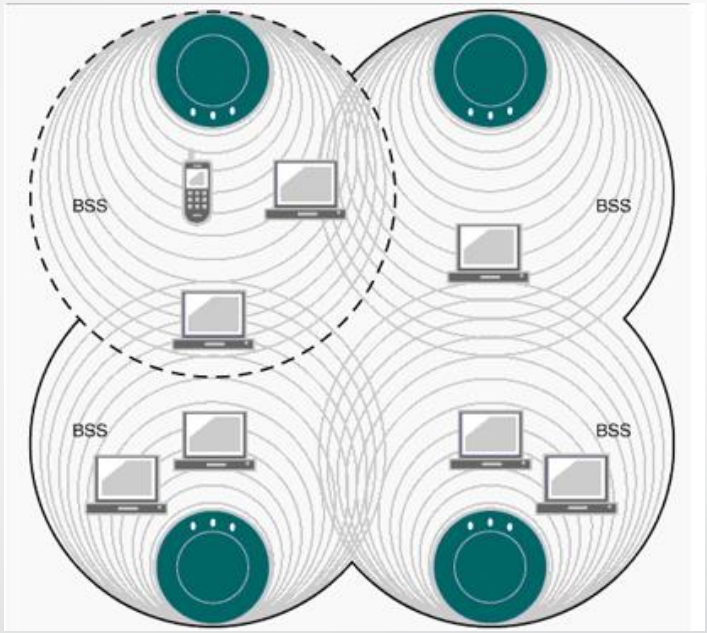


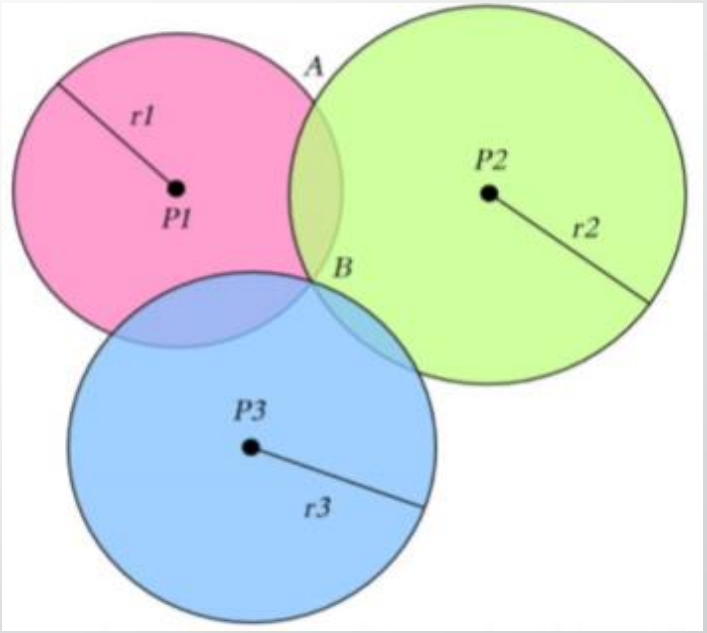
WIFI

- Indoor Localization
- Communicate Data to Computer

Indoor Localization

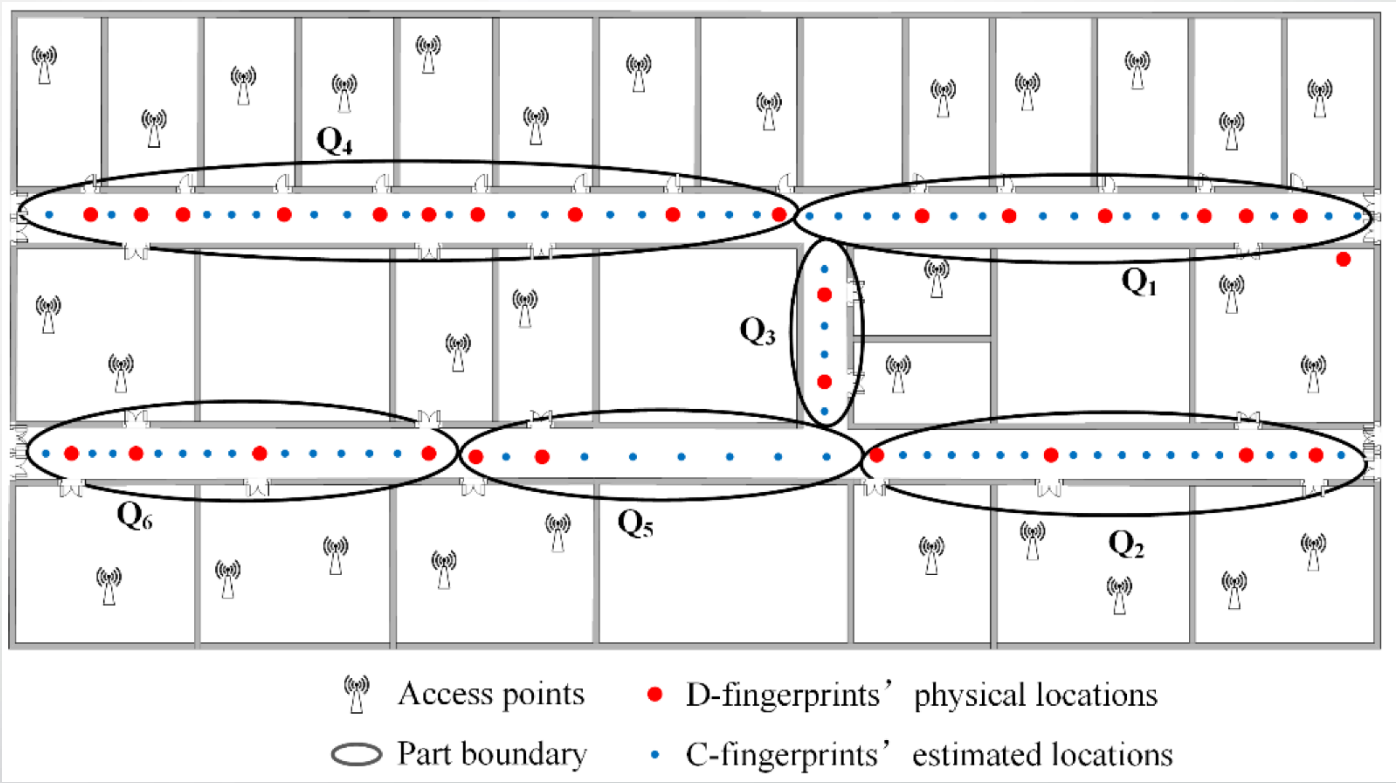
- Trilateration
  - RSSI (Received Signal Strength Ind.)
    - RSSI = 20log(d) + 20log(f) – 27.55
  - At least 3 distinct AP's signals
  - Physical locations of APs used
  - Real Time location





Indoor Localization

- Finger Printing
  - Pre-recorded RSSI map
  - Incoming RSSI data compared to map
  - "Closest data point" chosen



Data Communication

- Data sent over LAN to computer
- Computer will be responsible for:
  - Data Storage
  - Data processing (Localization)

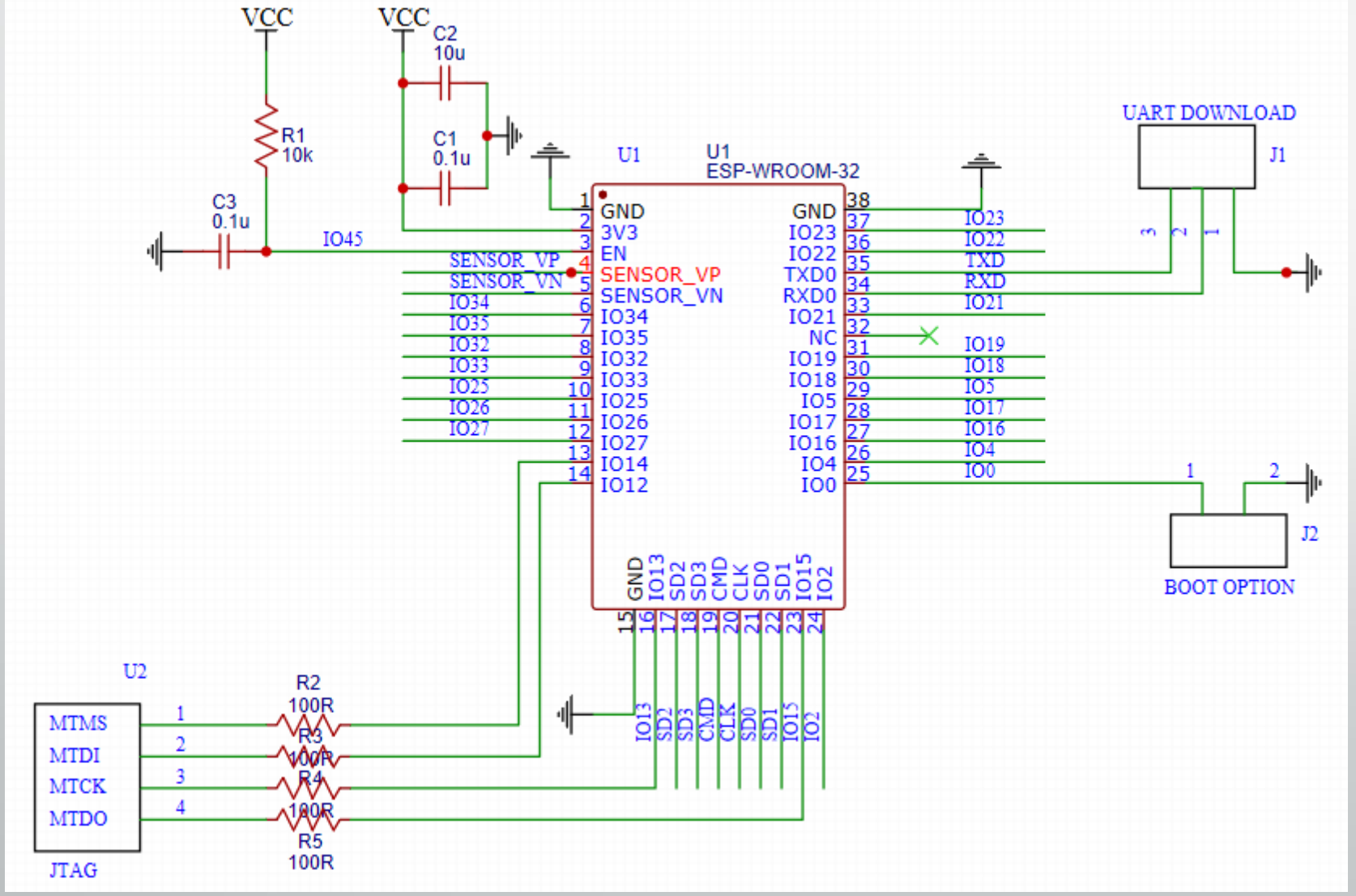
WIFI Chip
ESP32

- Two main requirements:
  - Integrated antenna
  - Good development support
- ESP32 was chosen

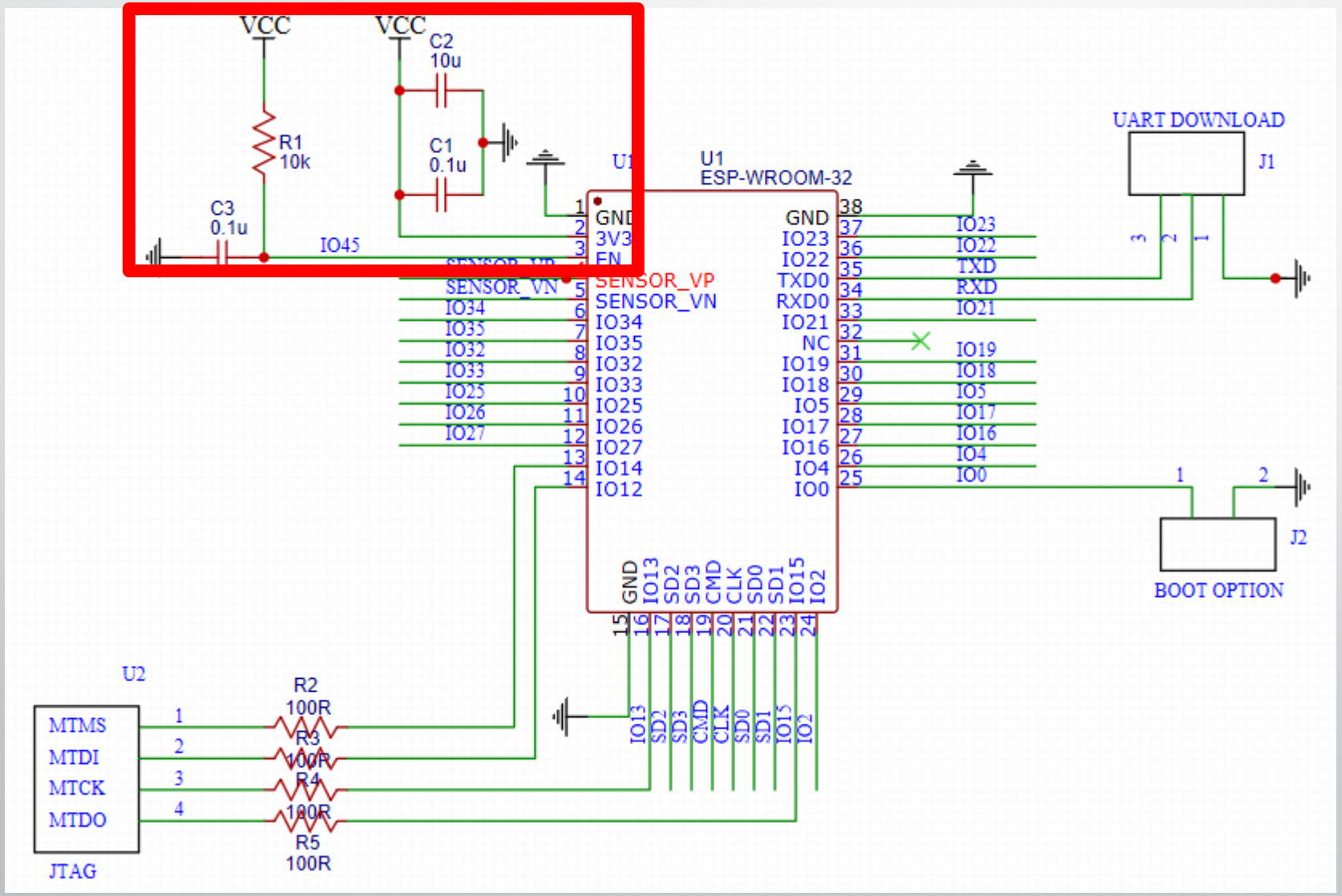
Spec	ESP32	CC3220
Current (mA) (LP Mode)	0.8 to 31 mA 240, 100 (Tx, Rx)	0.710 (DTIM 1) 286, 74 (Tx, Rx)
Size (mm^2)	25.50 x 18	20.5 x 25.50
Cost	$3.80 (mod.) $10.00 (dev)	$ 11.69 (mod.) $ 59.99 (dev)
Technology	BLE & BT 4.2	N/A

ESPRESSIF

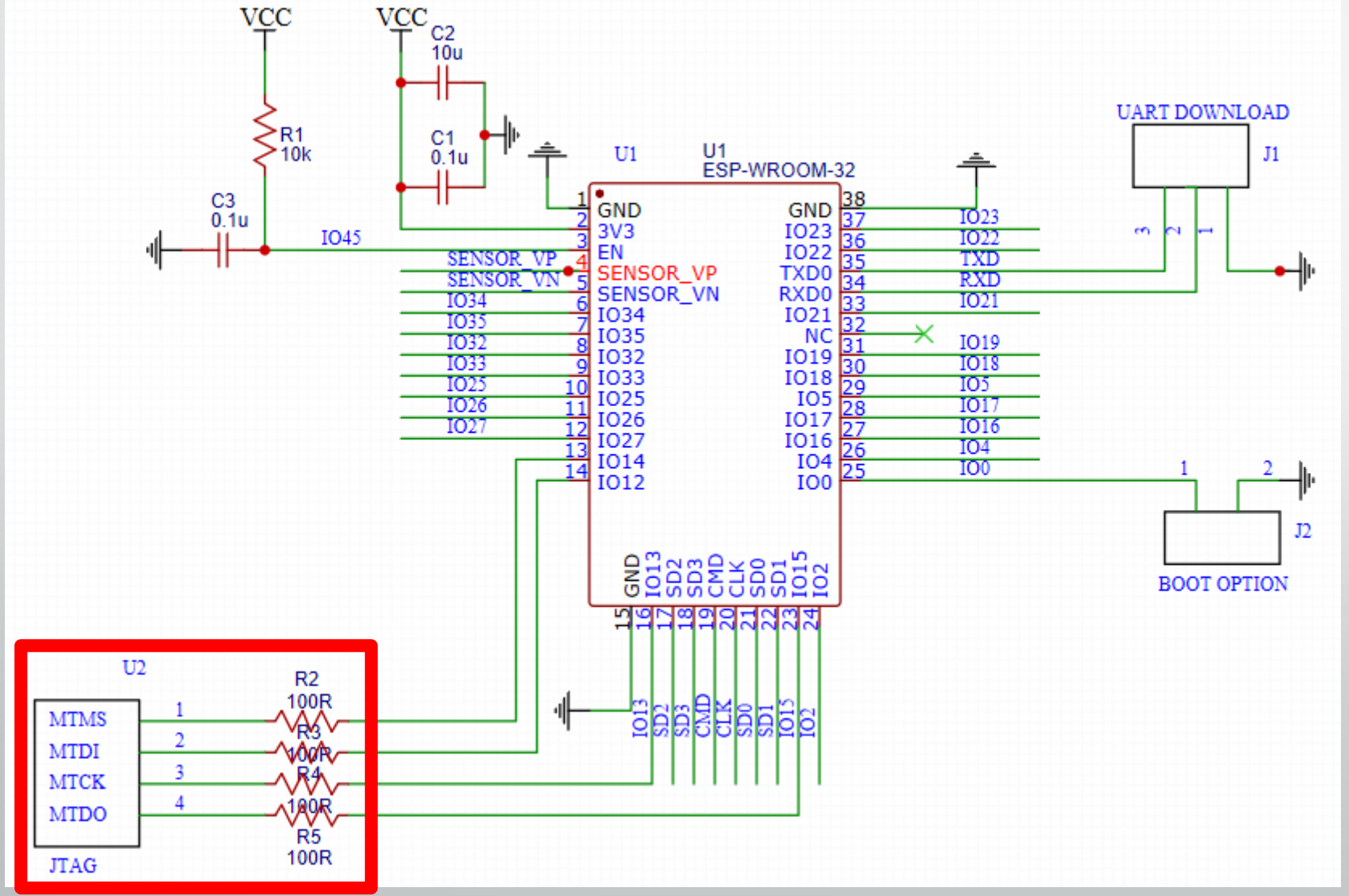
WIFI Schematic



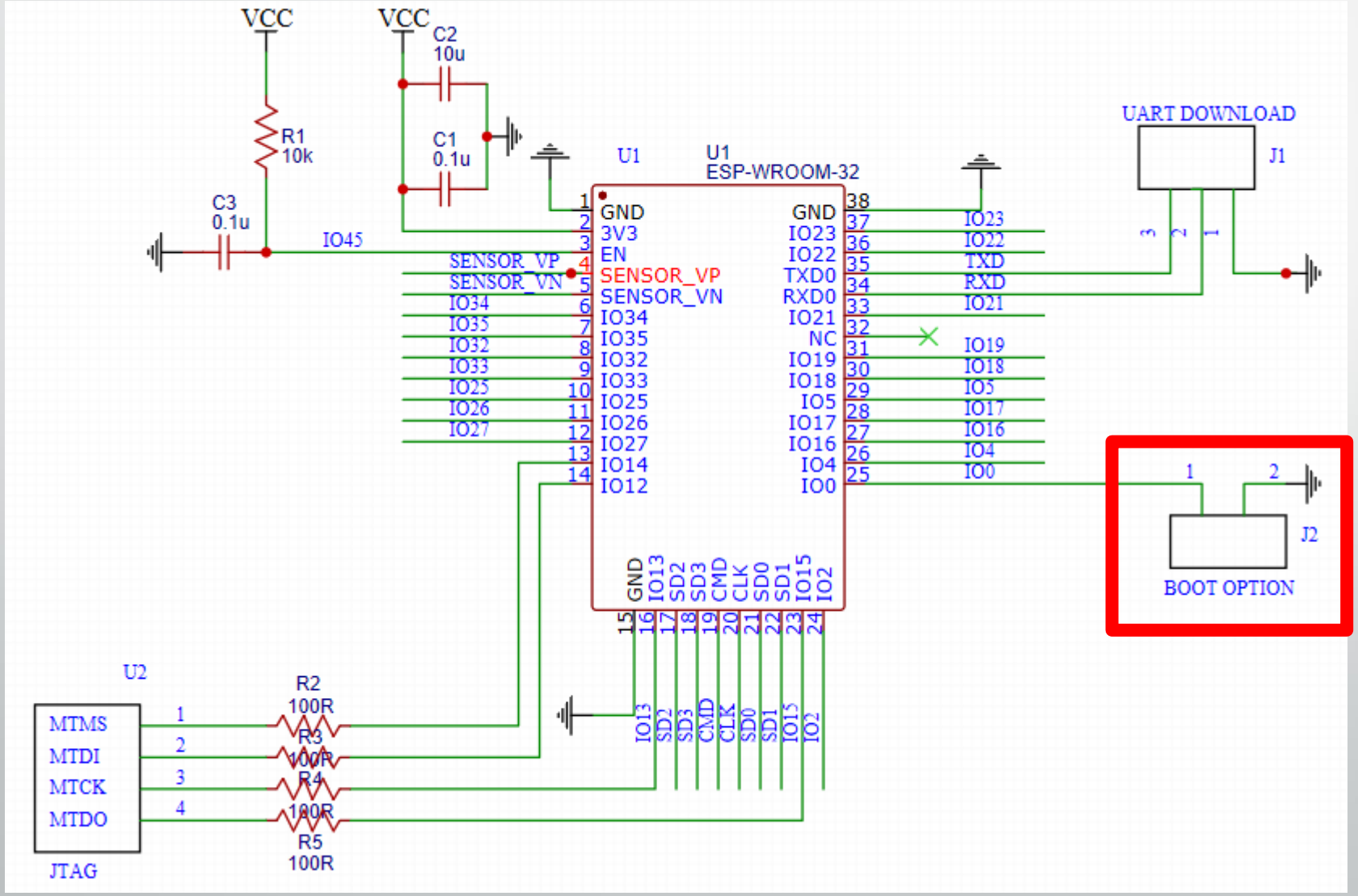
WIFI Schematic



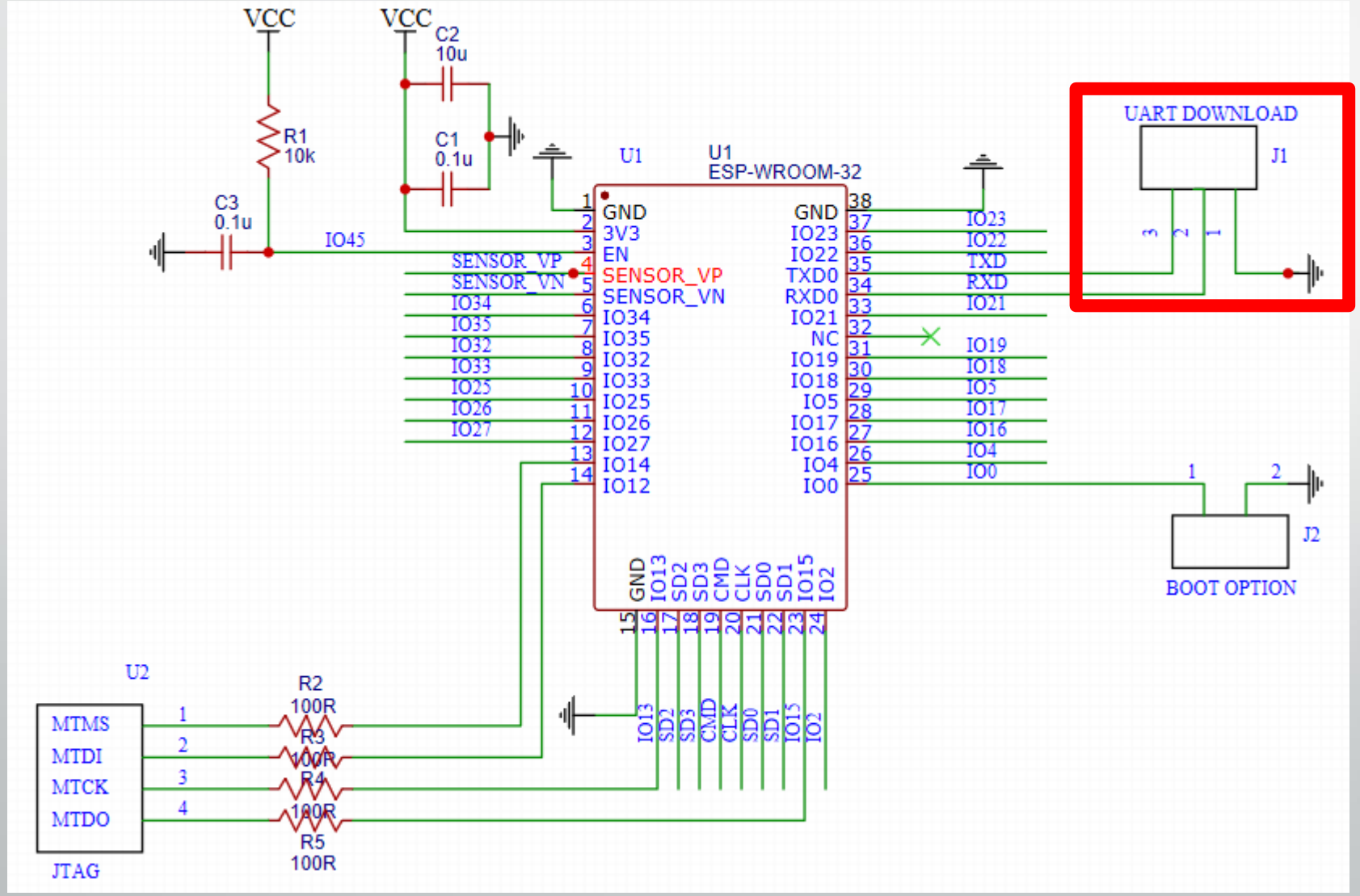
WIFI Schematic



WIFI Schematic



WIFI Schematic



NFC Chip

- Quick wireless Patient Identification
- NFC will identify which patient it is, then access their medical information over WIFI on the android device
- Not secure enough according to HIPPA (Health Insurance Portability and Accountability Act)

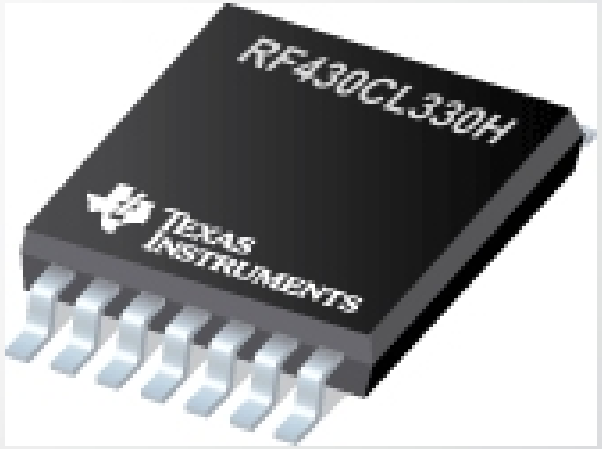
NFC

RF430CL330H

Includes:

- Direct Connect to MSP430
- Close range for pickup
- Read and write
- 3KB of SRAM
- Very Compact

Spec	Chosen Device
Current	2 mA
Size	5 mm x 4.4 mm
Cost	$1.16
Serial Com	I2C or SPI
Frequency	13.56 MHz



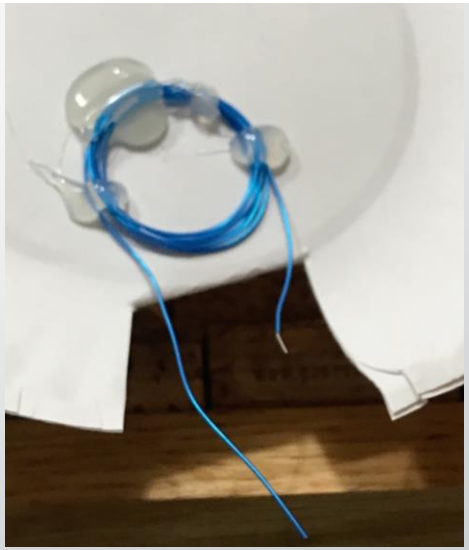
Texas Instruments

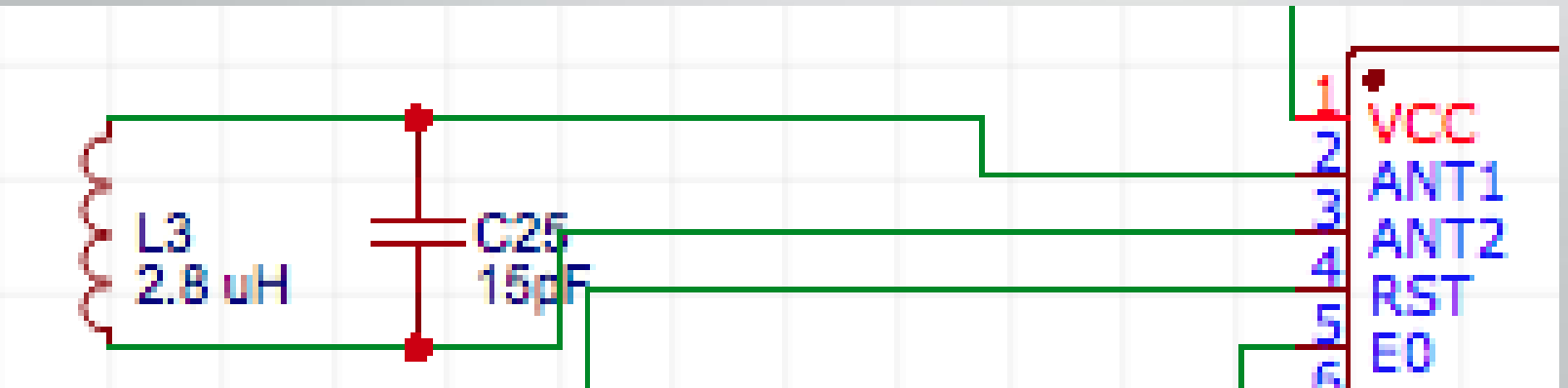
Antenna design

- The closer to 13.56MHz, the better the pick up range for android device
- Created our own antenna for testing by using formula

$$L_{loop} \approx N^2 \mu_o \mu_r \left(\frac{D}{2}\right) \cdot \left(\ln\left(\frac{8 \cdot D}{d}\right) - 2\right)$$

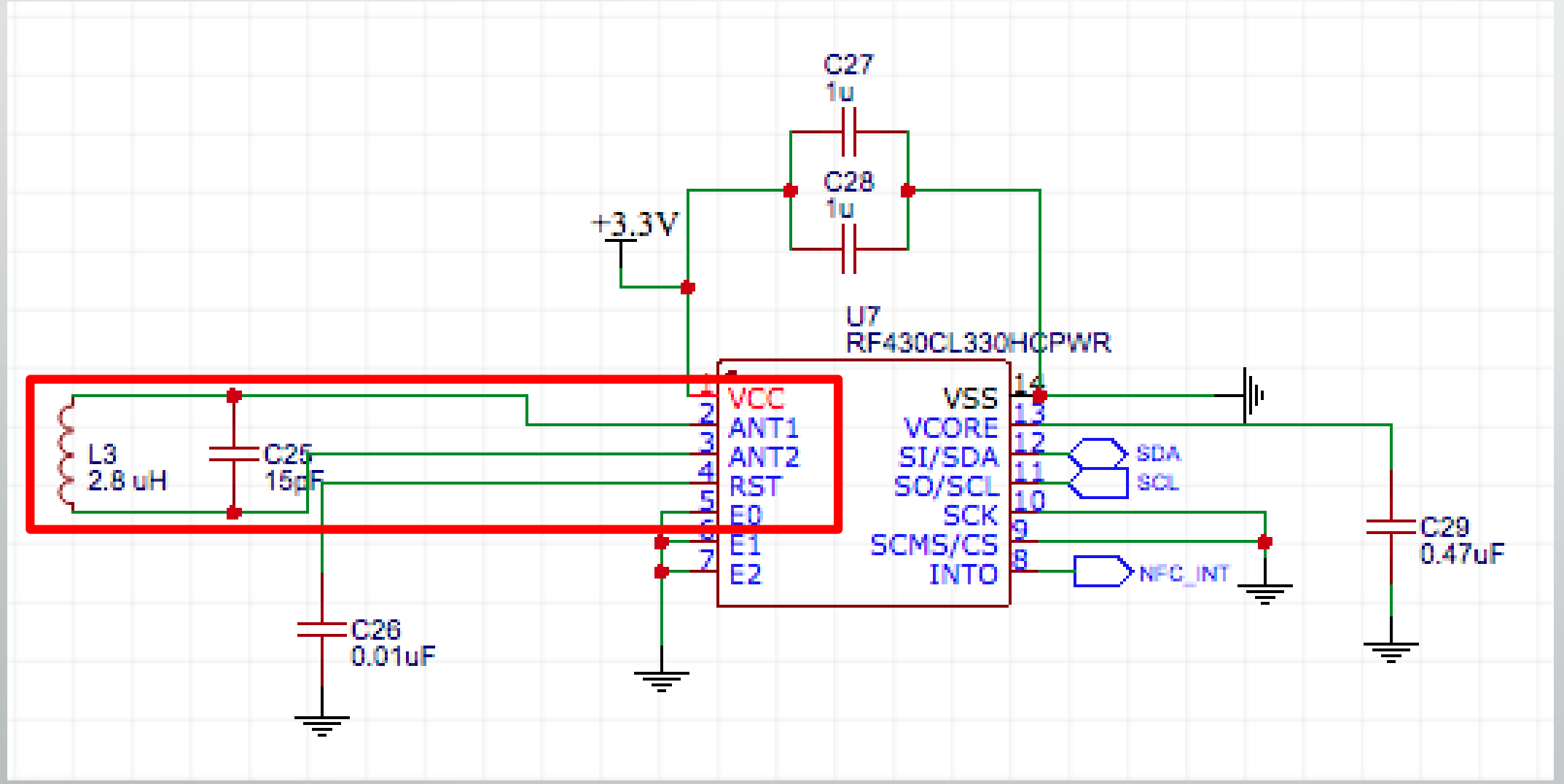
		MIN	NOM	MAX	UNIT
f_C	Carrier frequency		13.56		MHz
V_{ANT_peak}	Antenna input voltage			3.6	V
Z	Impedance of LC circuit	6.5		15.5	kΩ
L_{RES}	Coil inductance(1)		2.66		µH
C_{RES}	Total resonance capacitance(1) $C_{RES} = C_{IN}+C_{Tune}$		51.8		pF
C_{Tune}	External resonance capacitance		$C_{RES} - C_{IN}$(2)		pF
QT	Tank quality factor		30		
C_{IN}	Input capacitance	ANT1 to ANT2, 2 V RMS	31.5	35	38.5	pF



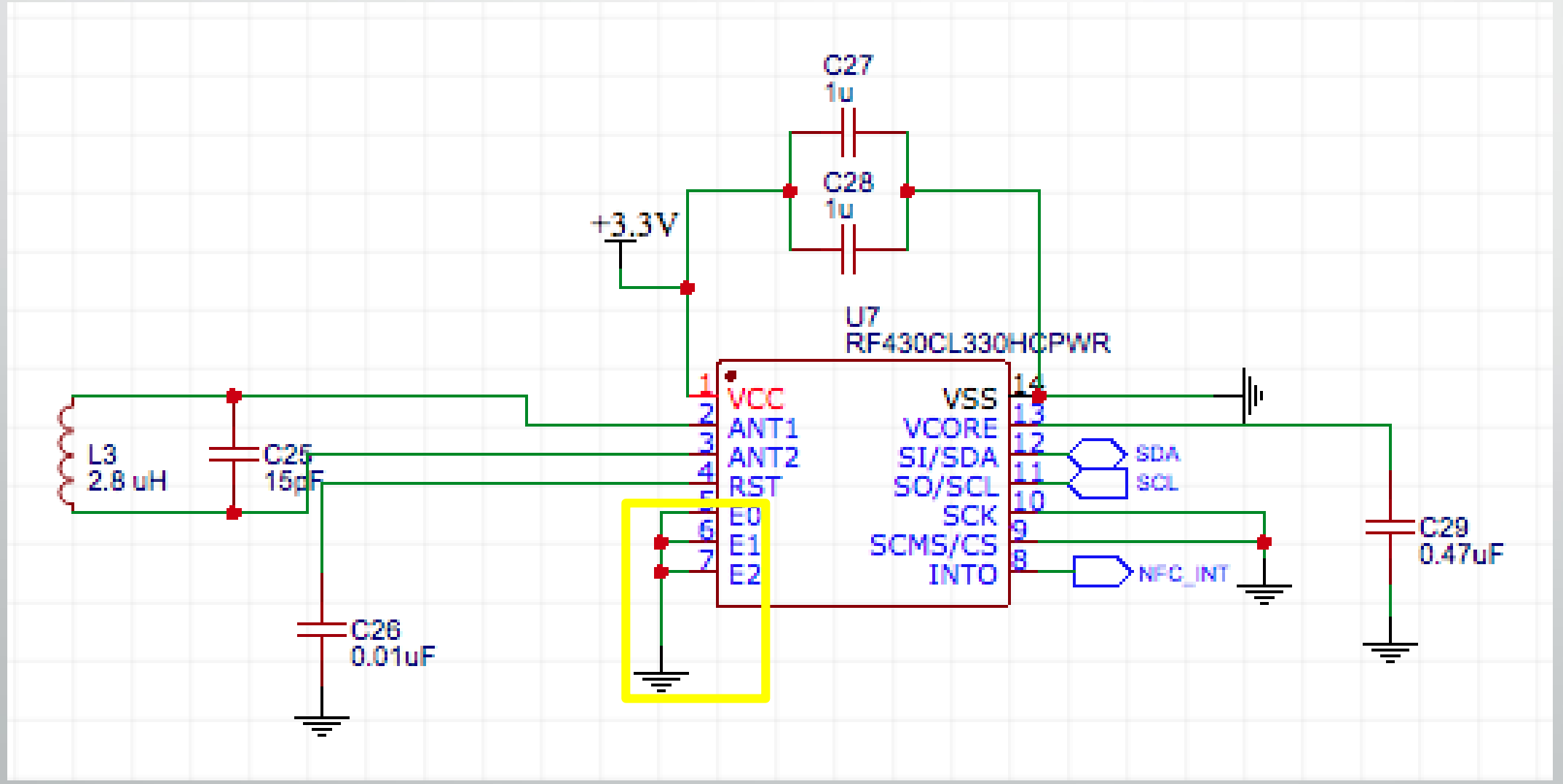


fRES = 1 / [2π(LRESCRES) 1/2] =
1 / [2π(LRES(CIN + CTune))1/2] ≈ fc

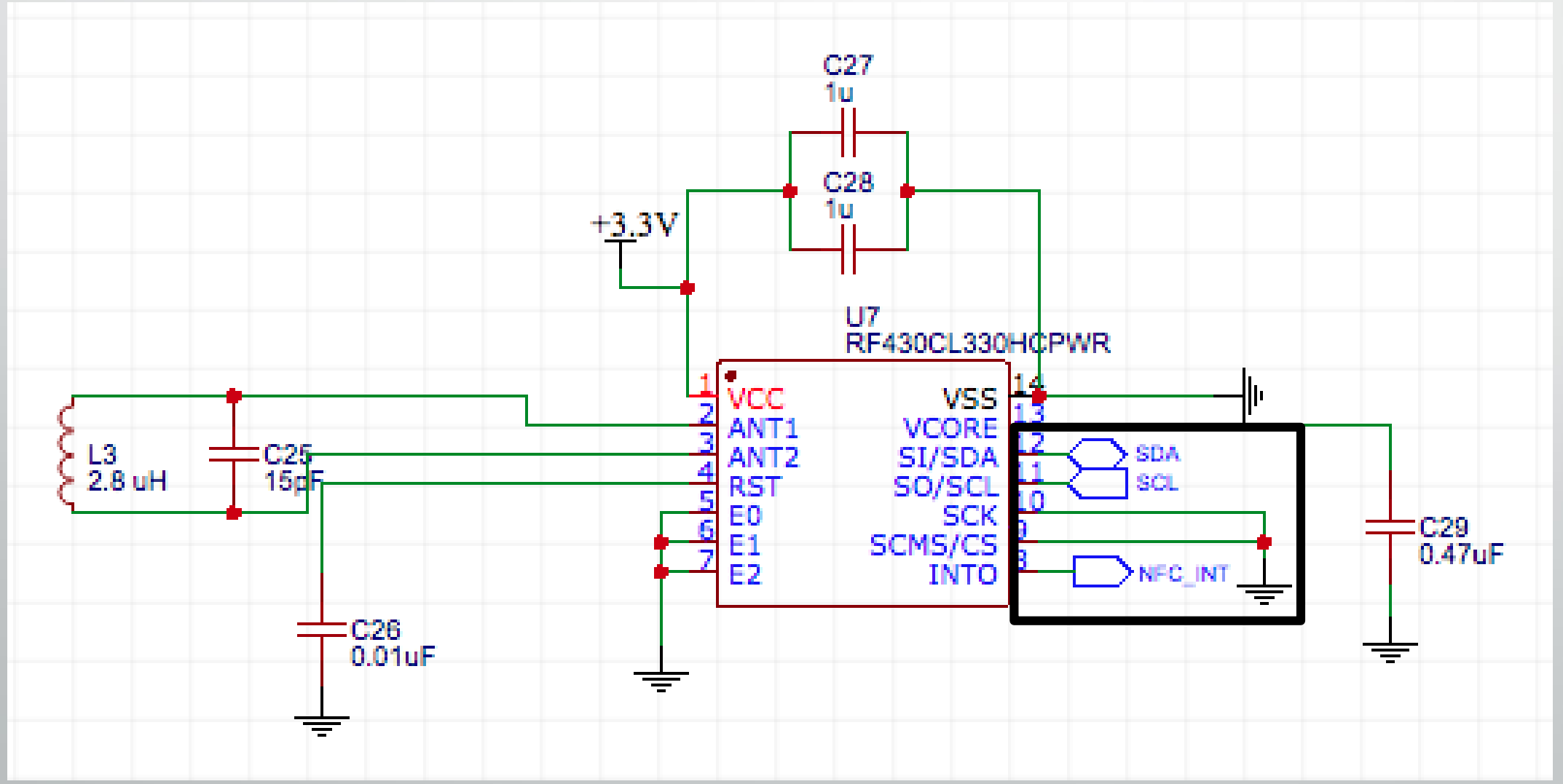
NFC Schematic



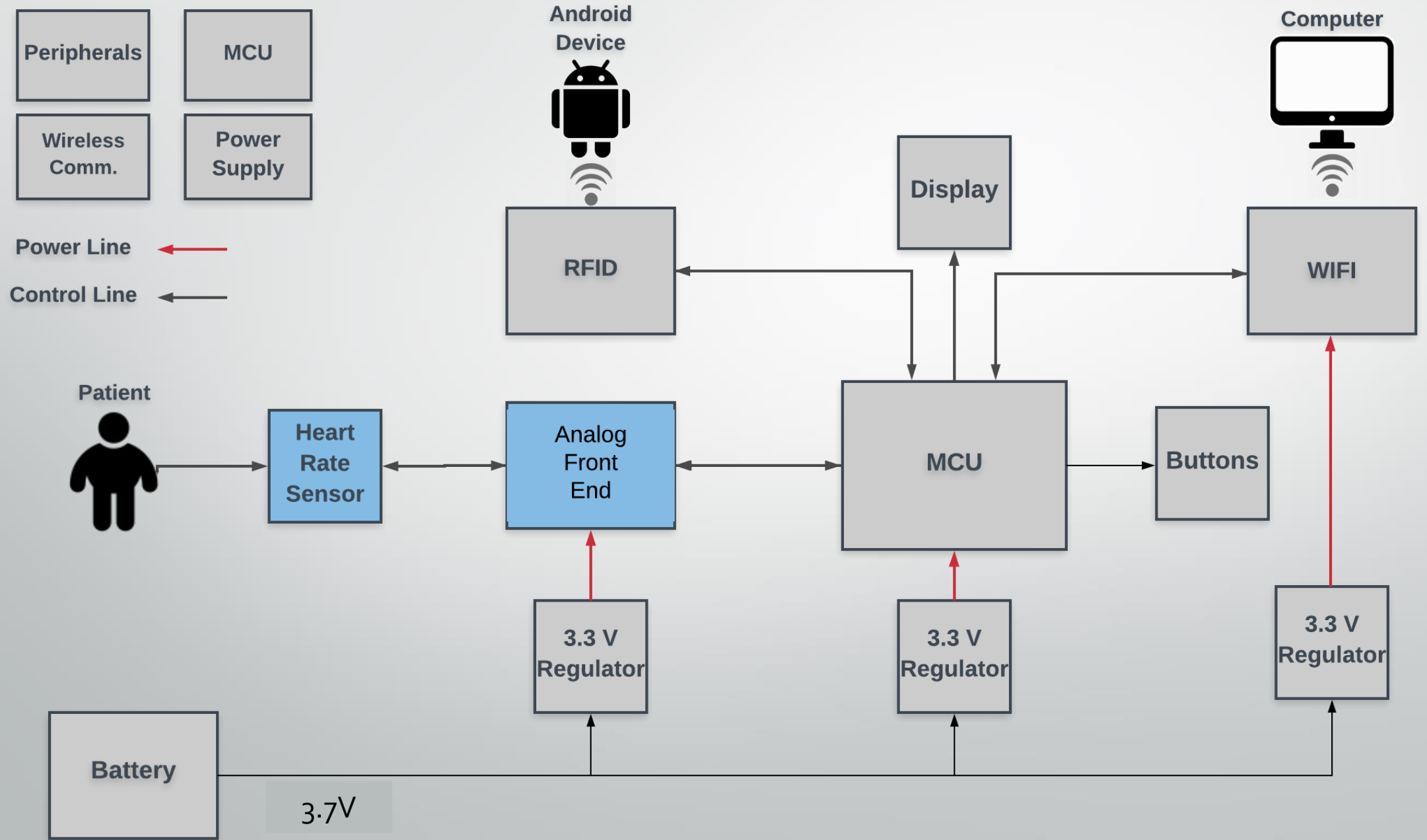
NFC Schematic



NFC Schematic



Heart Rate

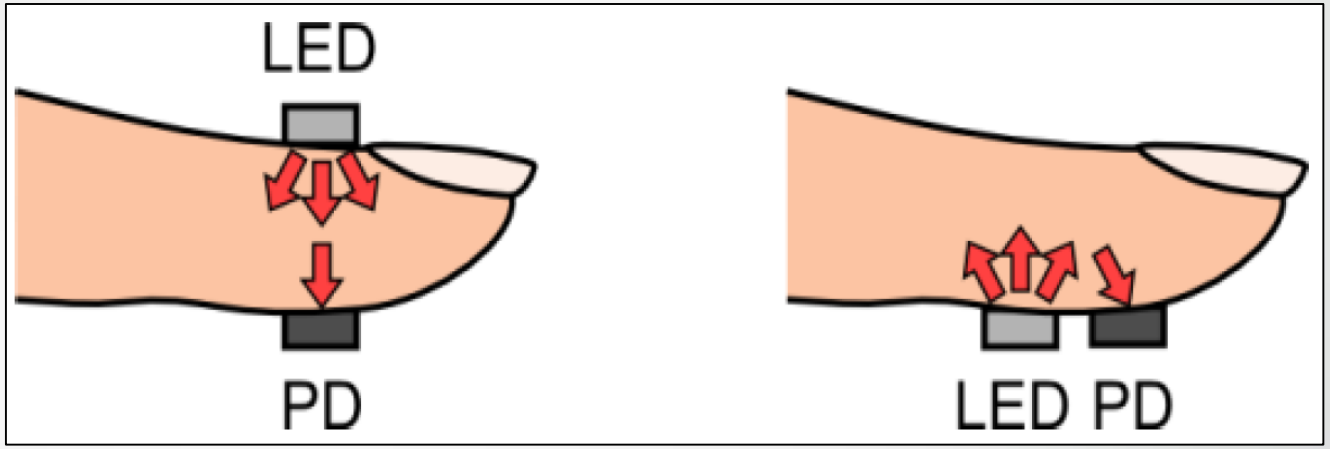

Peripherals
MCU
Wireless Comm.
Power Supply
Power Line
Control Line
Android Device
Computer
RFID
Display
WIFI
Patient
Heart Rate Sensor
Analog Front End
MCU
Buttons
3.3 V Regulator
3.3 V Regulator
3.3 V Regulator
Battery
3.7V

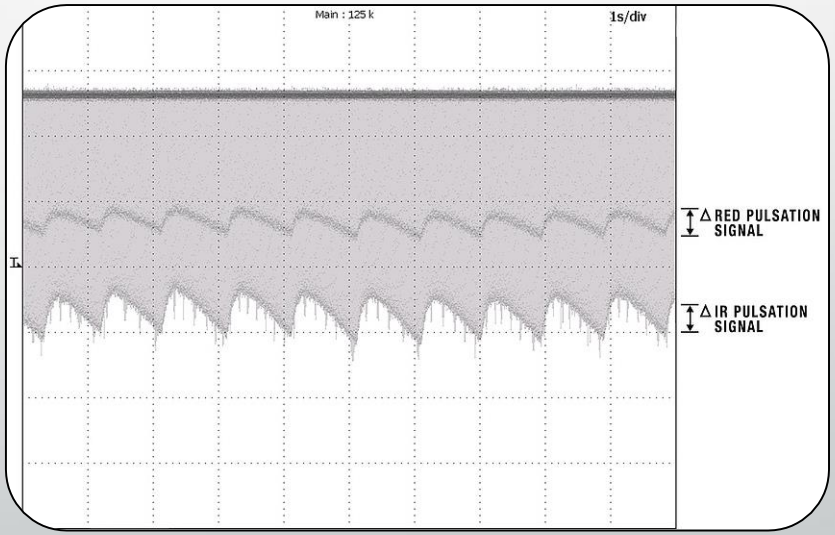
Pulse Oximetry

- Measures SpO_2 blood oxygen saturation using a LED and Photodiode
- SpO_2 calculated as a ratio of oxidized hemoglobin to deoxy-hemoglobin

$$SpO_2 = HbO2 / (Hb + HbO2)$$

- **Hb** absorbs more and reflects **less visible light** (600-750 nm)
- **HbO2** absorbs more and reflects **less infrared light** (800-1000 nm)

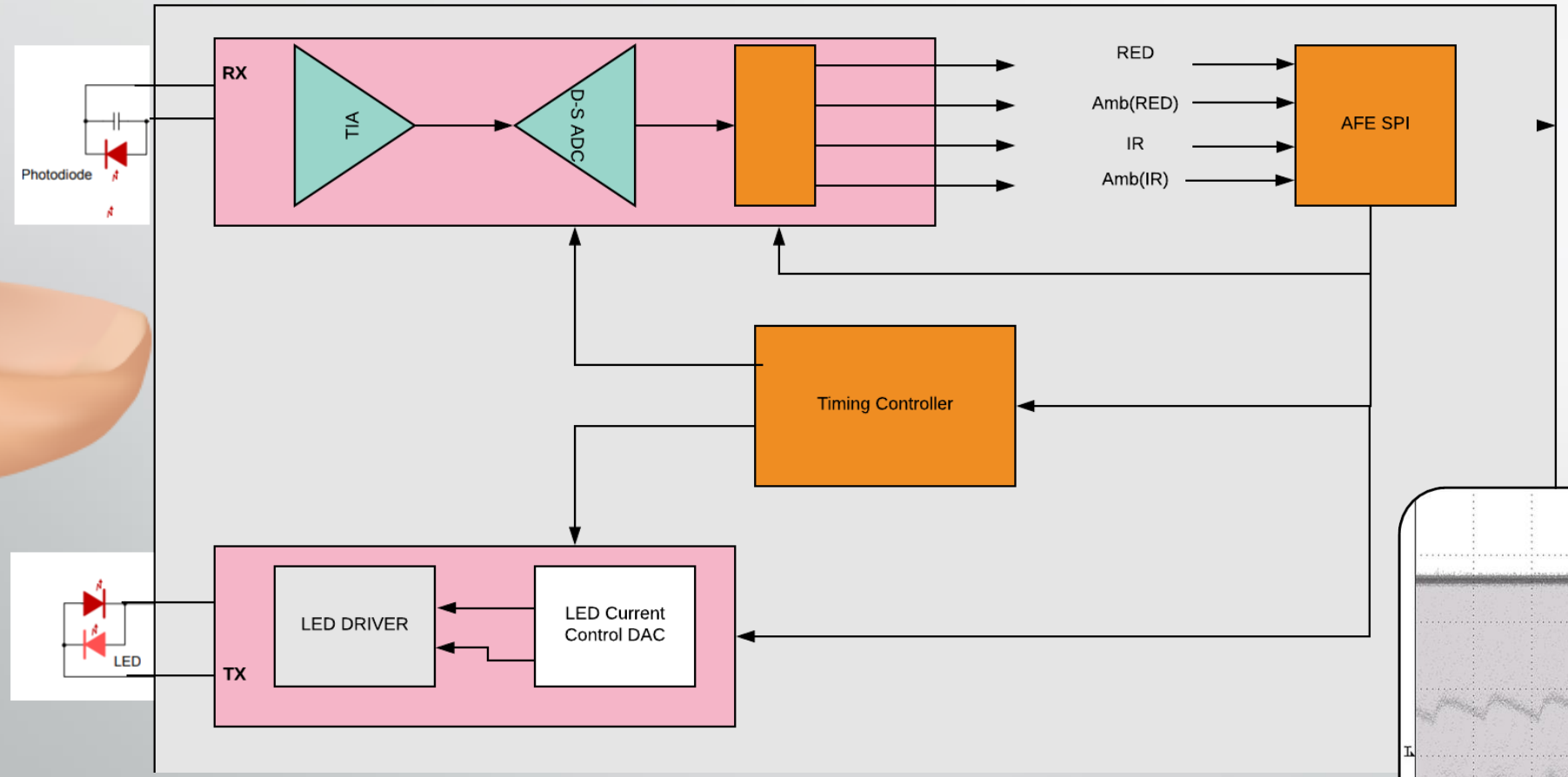




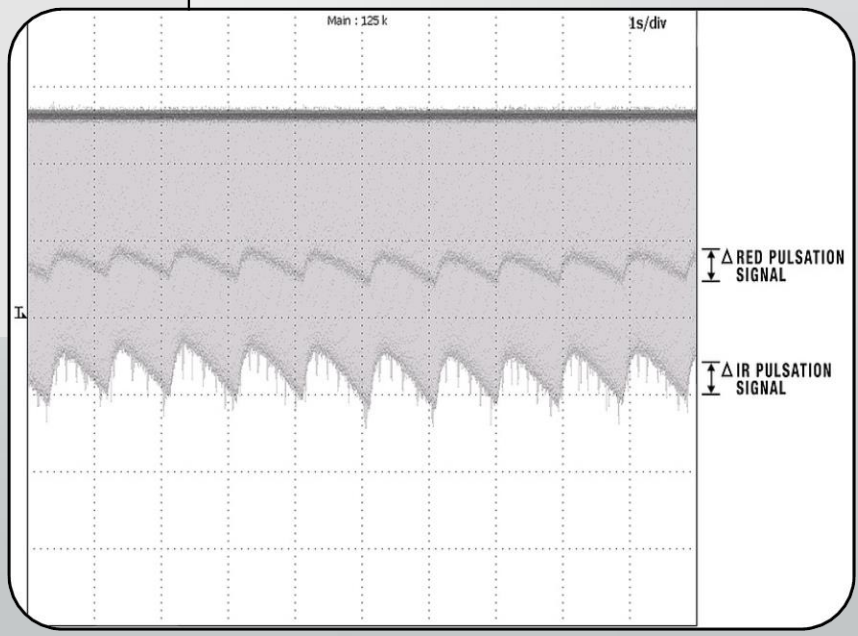
Nellcor DS-100

Integrated Analog Front End

Texas Instruments AFE4400



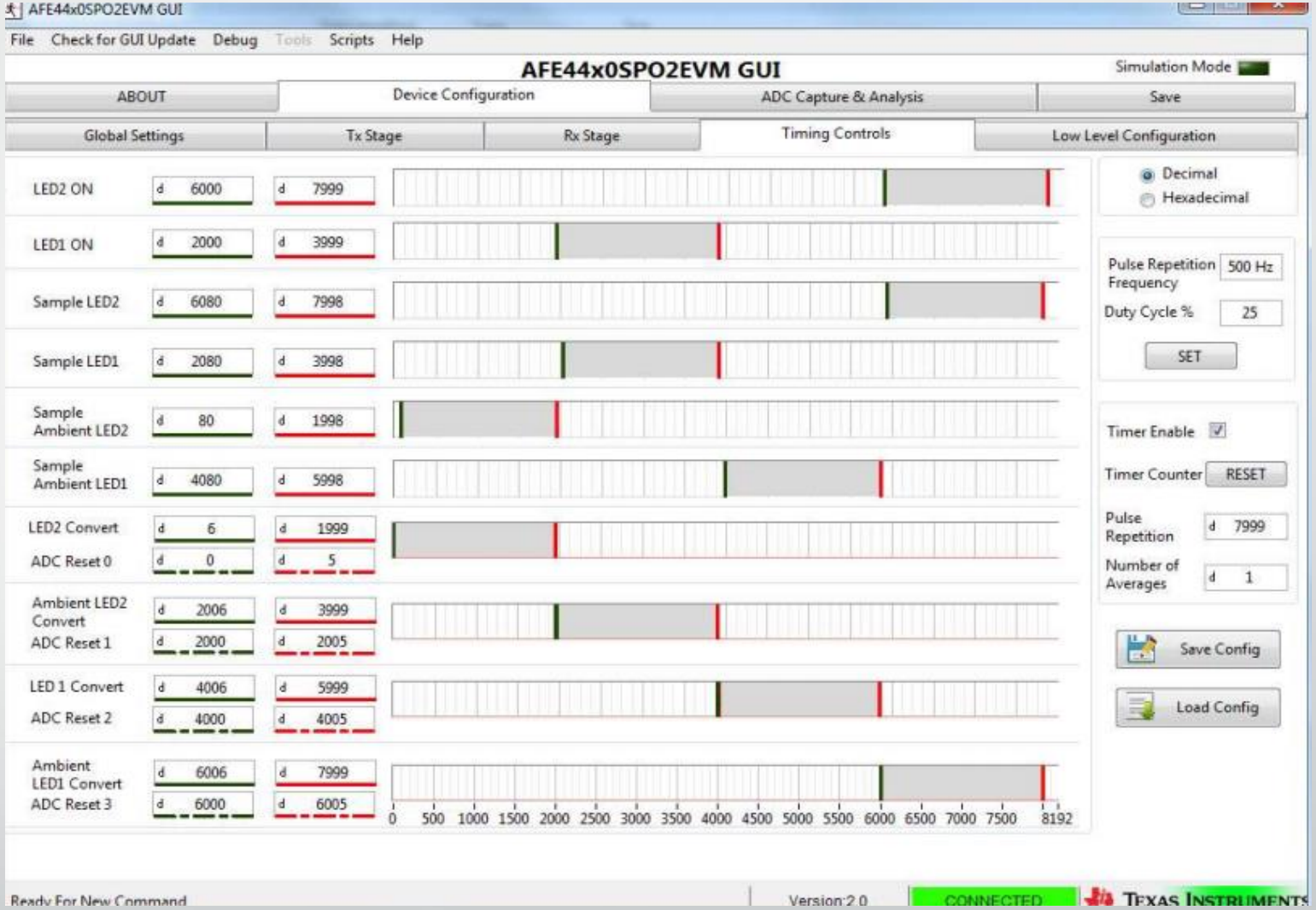
TEXAS INSTRUMENTS



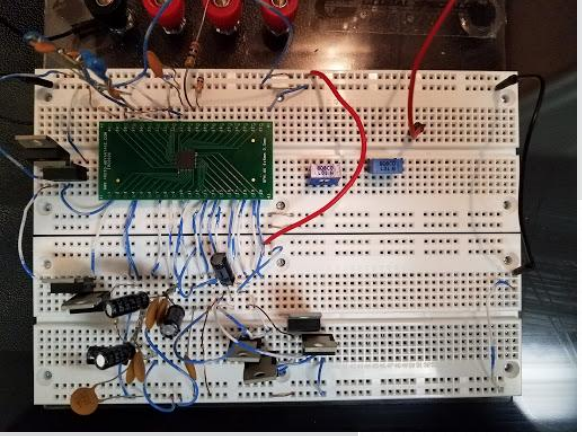
Spec	Cost	Size	Current
AFE4400	$2.50	6X6mm^2	100uA

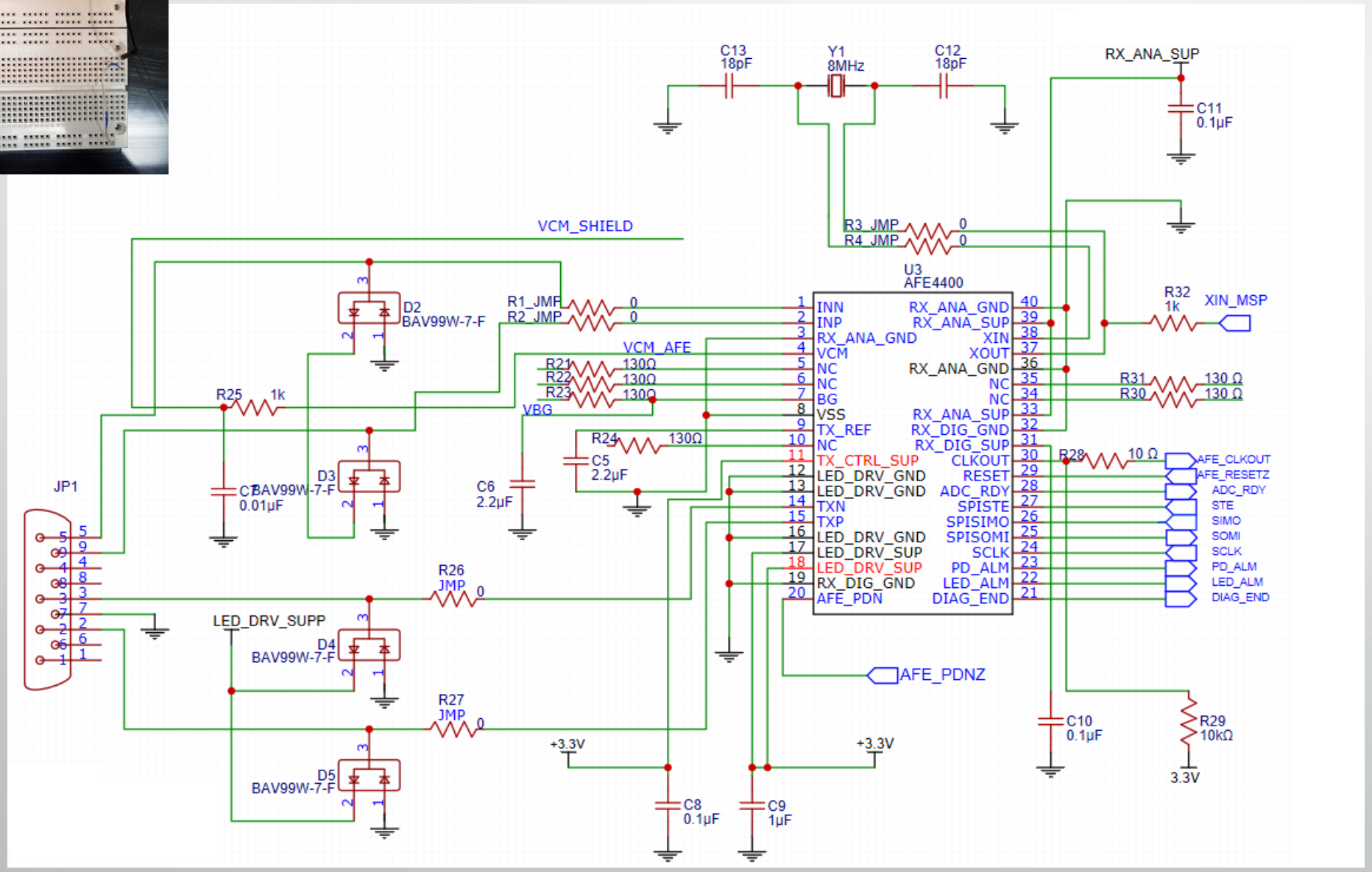
Texas Instruments AFE4400SpO2 Evaluation Demo Kit

- Development board for AFE440 includes GUI and firmware

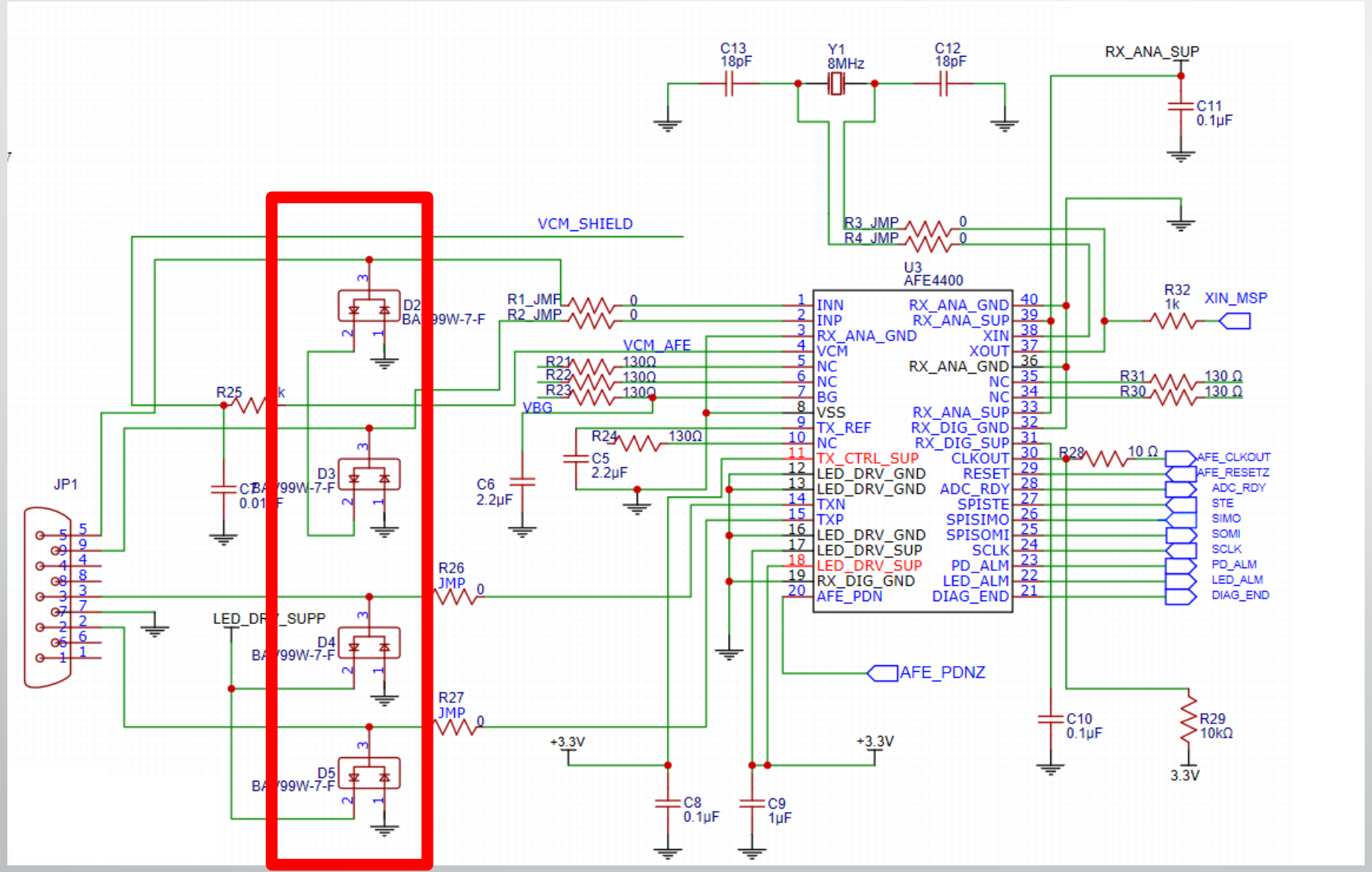


AFE Schematic

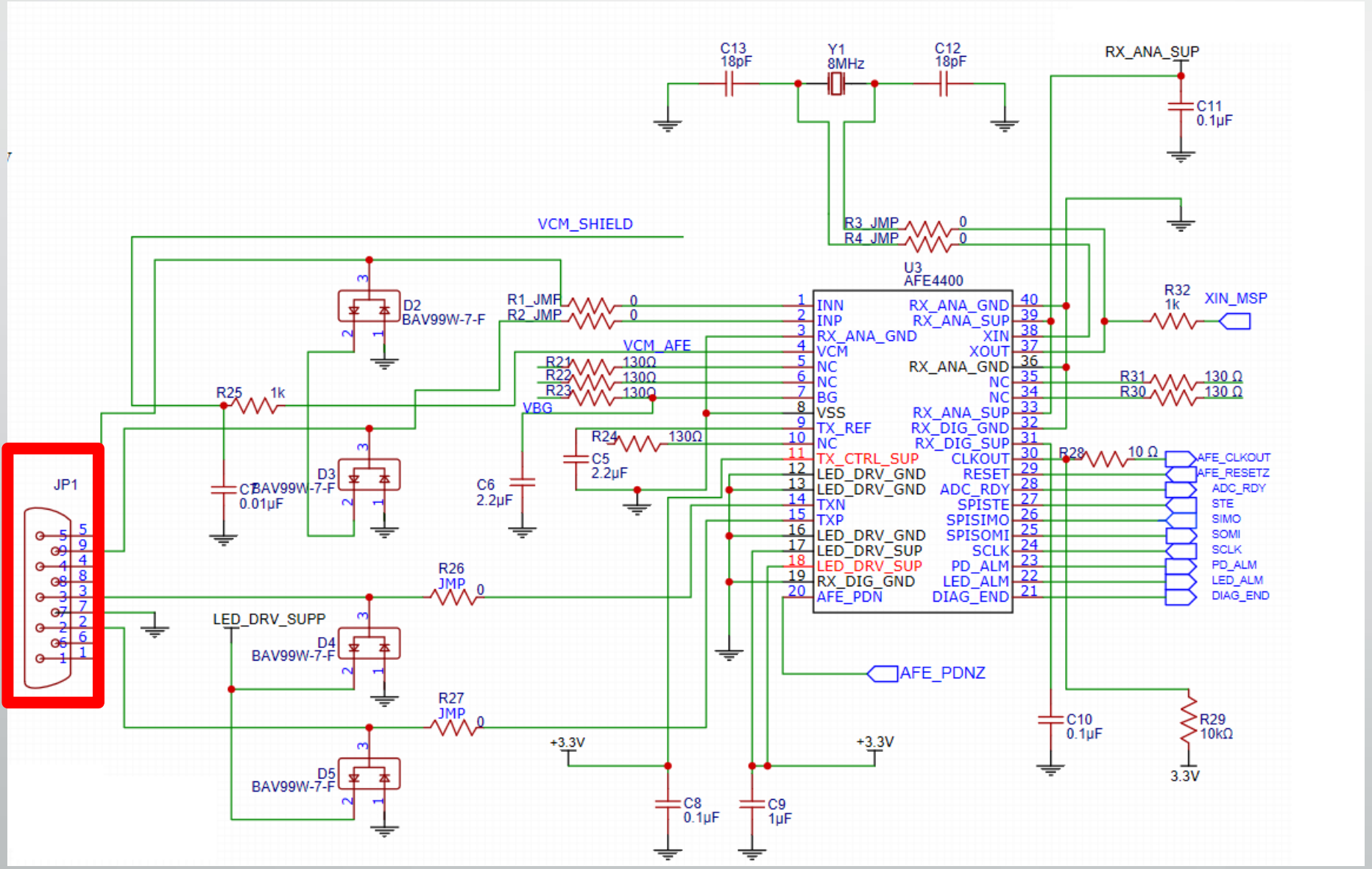




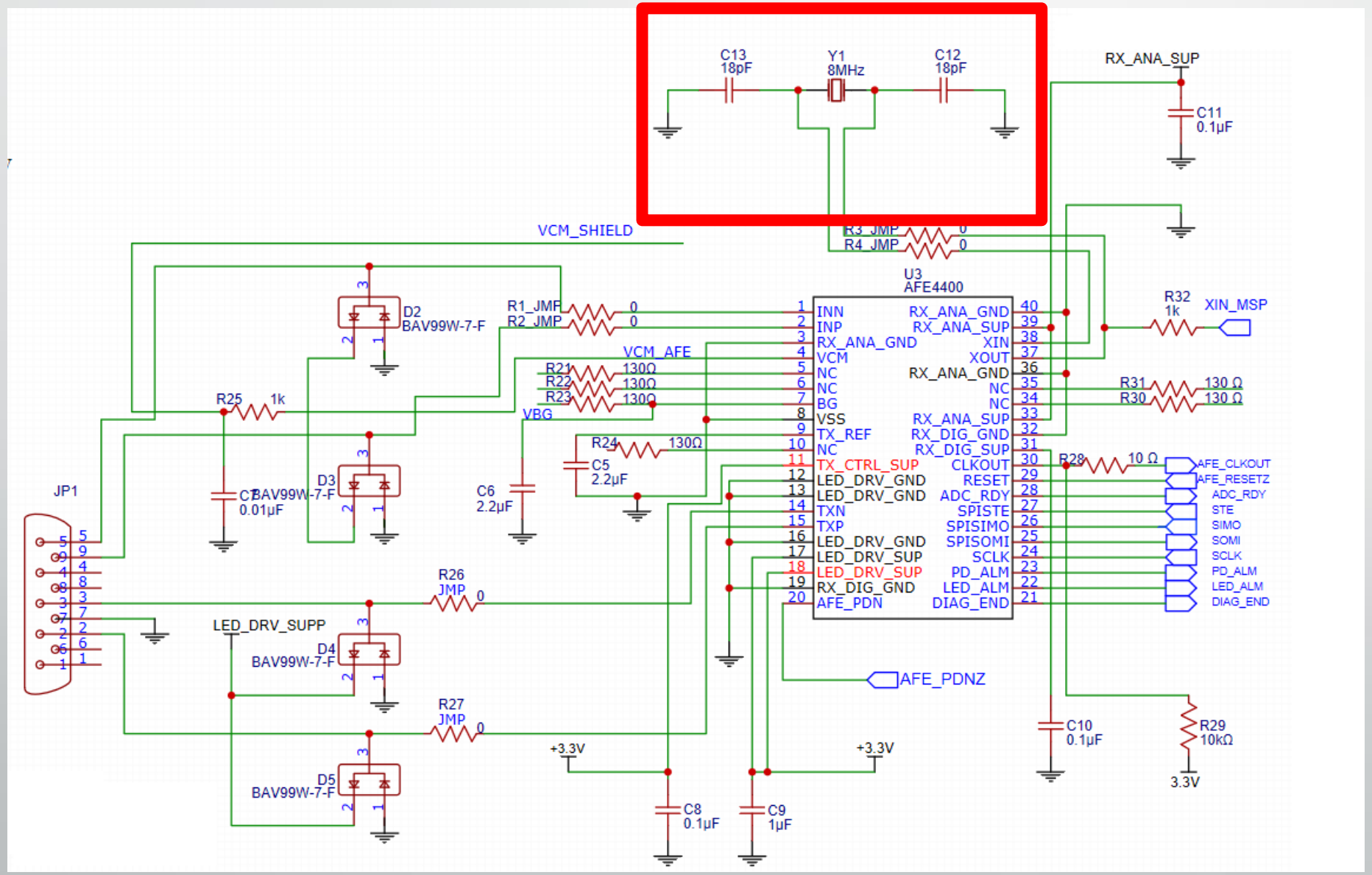
AFE Schematic



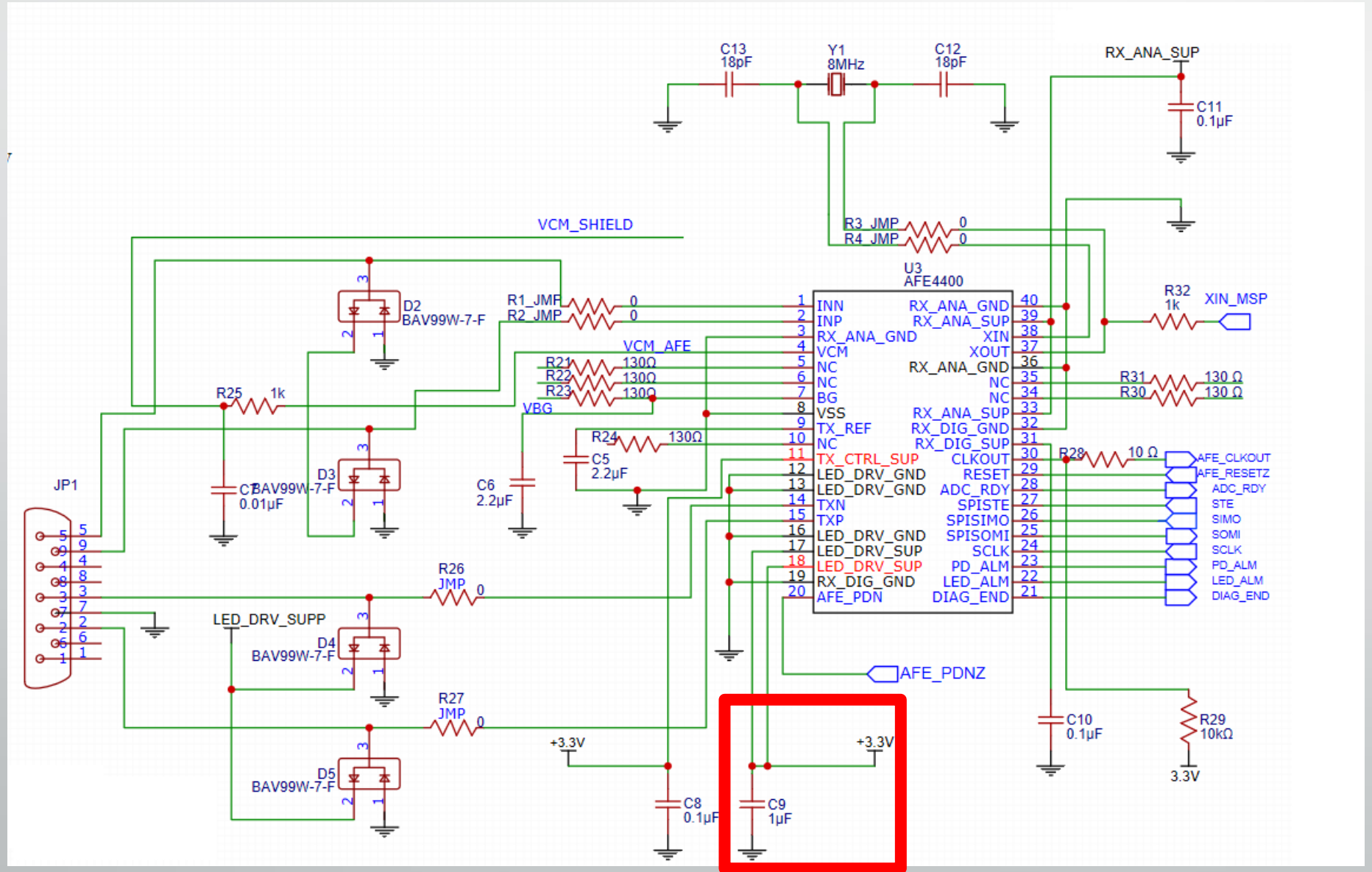
AFE Schematic



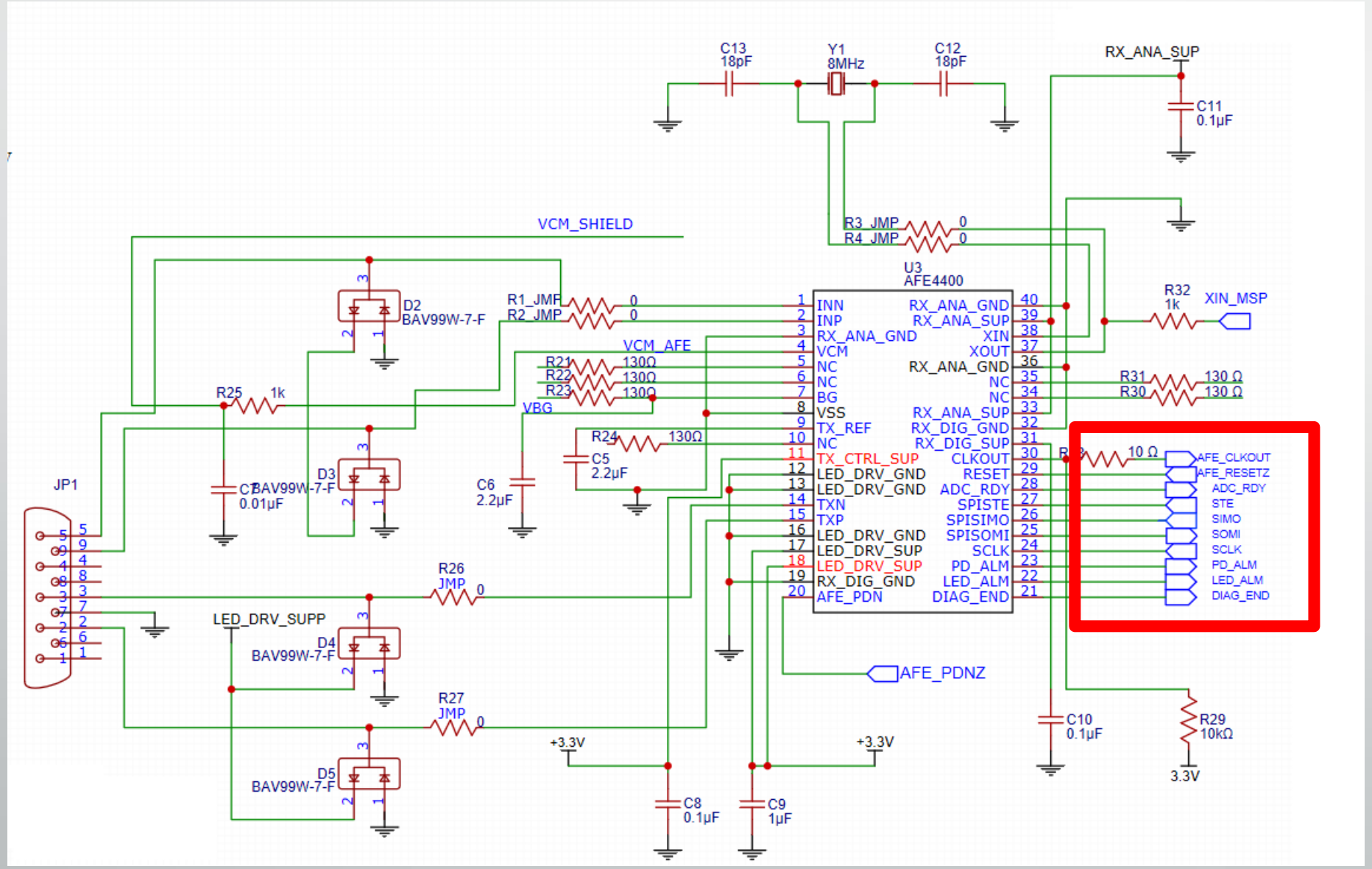
AFE Schematic



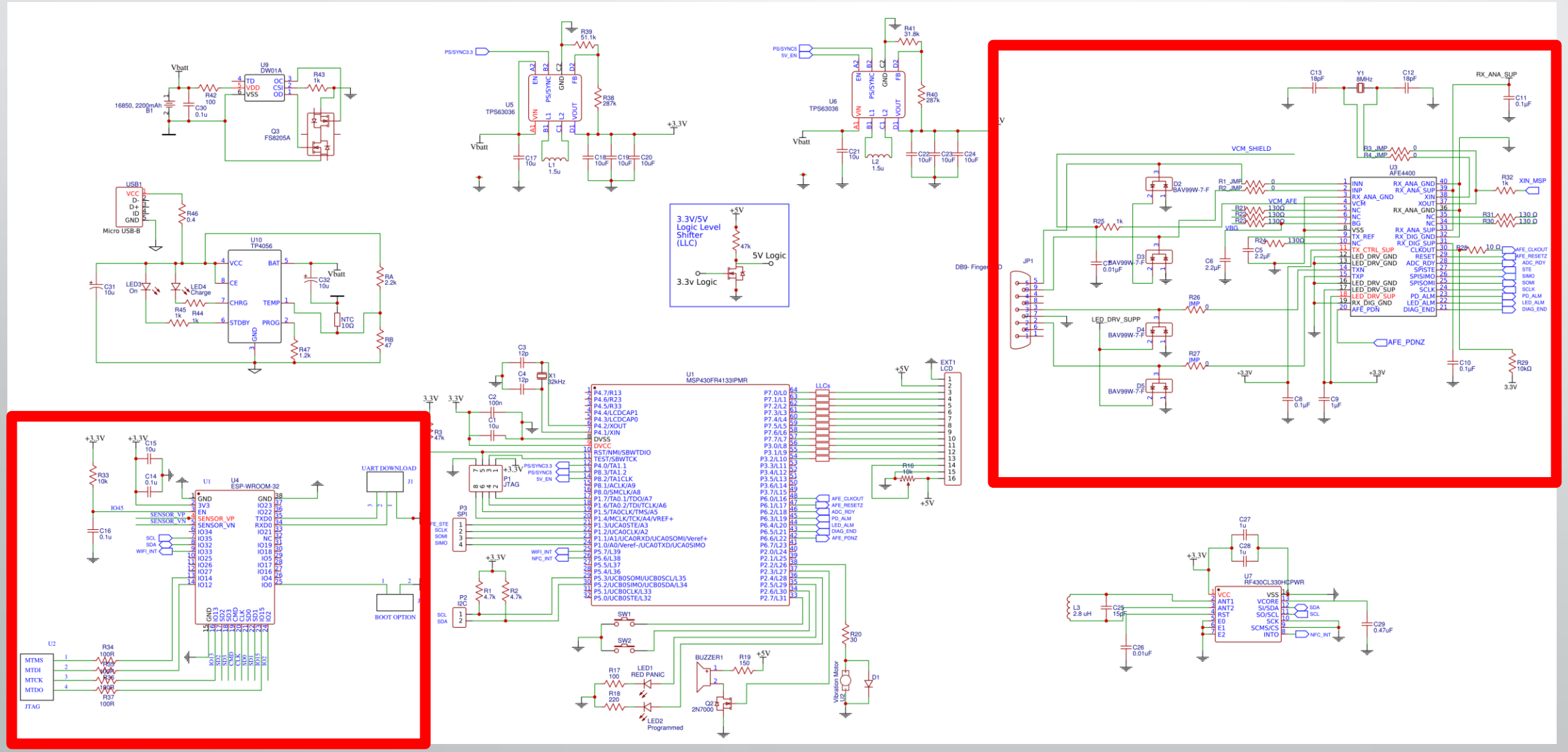
AFE Schematic



AFE Schematic



Overall Schematic



Cost Table

Part	Cost
MSP-EXP430FR413	$ 14.490
AFE4400 Breakout Board	$ 12.990
PA0033 (NFC Breakout Board)	$ 3.6900
AFE4400SPO2EVM	$ 149.00
BOOSTXL-SENSHUB	$ 49.990
IRFP250NP Power MOSFET	$ 3.1400
AFE4400 Breakout Board	$ 12.990
Shipping	$ 30.000
Total	$ 276.00
Saved by TI LAB	$ 215.12
Total	$ 61.17

Part	Cost	Part	Cost
1N4448	$ 0.0167	Micro USB-B 5P-Female-SMT_C40940	$ 0.1099
Crystal	$ 0.0959	MSP430FR4133IPMR	$ 2.8200
AFE4400	$ 2.5000	PCB	$ 20.0000
Battery 2200mAh	$ 3.0000	RF430CL330HCPWR	$ 1.2900
BAV99W-7-F	$ 0.0696	SMD Capacitors	$ 2.3940
Buzzer	$ 0.1793	SMD Inductor	$ 9.0000
DW01A	$ 0.0227	SMD Resistor	$ 9.3545
ESP-WROOM-32	$ 3.8000	Thermistor NTC	$ 0.1037
Finger Probe	$ 20.0000	TP4056	$ 0.2452
FS8205A	$ 0.2334	TPS63036	$ 3.3400
NHD-C0216AZ-FSW-GBW	$ 10.1100	Vibration Motor	$ 1.2000
LEDs	$ 0.0924	Case 3D Print	$ 0.00
		Total	$ 89.98

Division of Labor

	NFC	Heart Rate	Localization	MCU	Power
John Alcala		P		S	
Carter Lankes	P				P
William Toledo	S	S	S	P	S
Josue Ortiz	S		P	S	

P - Primary
S - Secondary

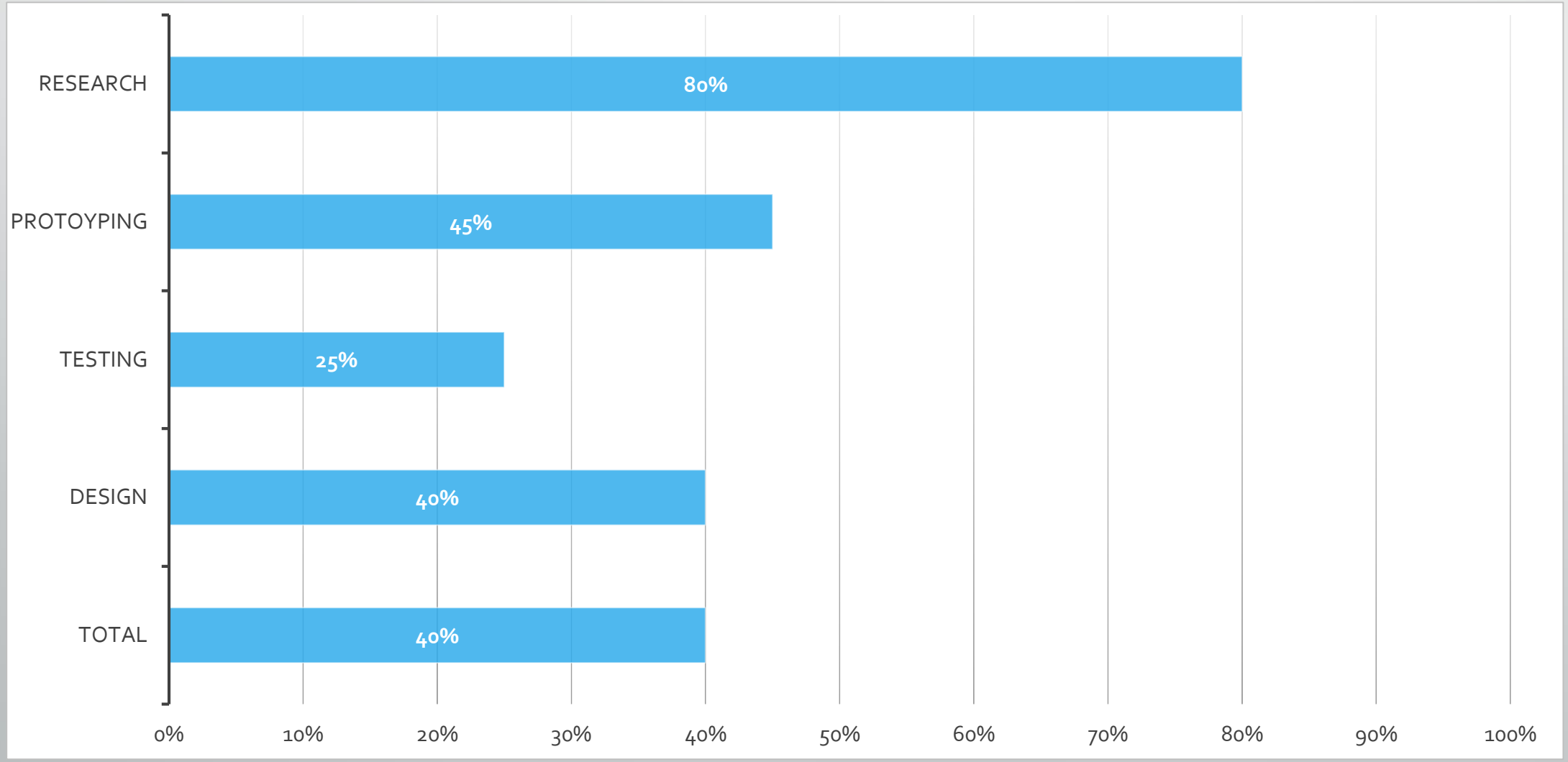
Difficulties and Obstacles

1. Connection to UCF WIFI networks
2. Inexperience with Server Applications
3. Android App
4. Very Small, SMD components

Extended Goals

1. Advanced GUI Phone App to Read and Write NFC
2. Encryption of Patient-ID, for NFC
3. OLED display for patient Info
4. Water Proof/Sterile
5. Reduce Size to <50X50 mm^2

Progress


RESEARCH
80%
PROTOYPING
45%
TESTING
25%
DESIGN
40%
TOTAL
40%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Questions?