Prepaid Energy System

Group 21

- Youssef Ojeil (EE)
- Michael Cuervo (EE)
- MD.S. Rahaman (EE)
- Sahin Okur (EE)

Sponsored by:

Supervised by Dr. Chung-Yong Chan

Goals and Objectives

- Alternative pre-paid solution to conventional utility billing
- RFID/NFC technology allows for quick payment
- Enables the Internet of Things (IoT) so the user can always be connected to the system
- Android application provides the user with real-time data in the palm of their hands
- Easy access to statistics gives the user more awareness and control of usage
- Automatic connect/disconnect capability relieves the burden from the utility providers

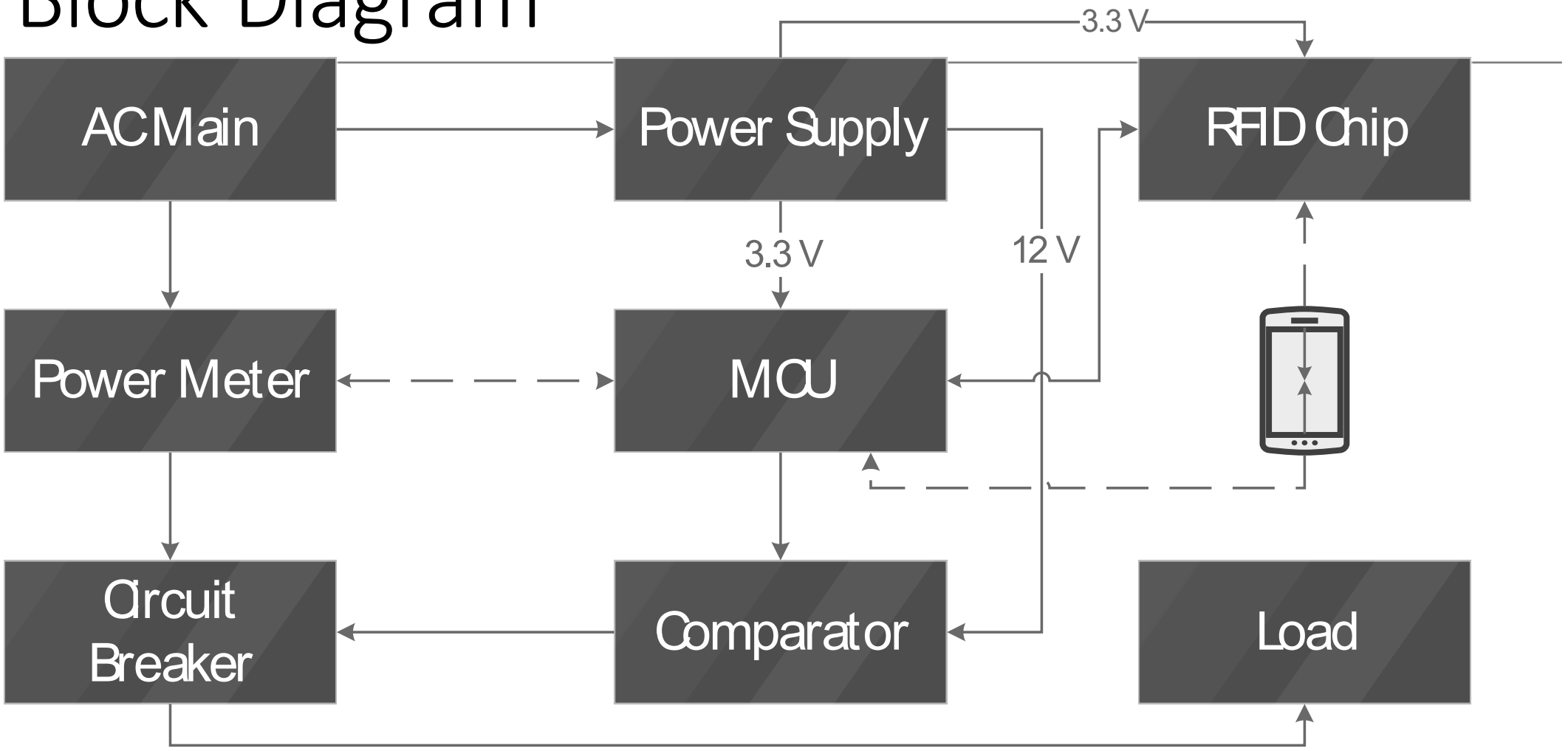
Requirements

- Must facilitate mobile payment via RFID/NFC
- Incorporating Texas Instrument's 3 Phase Power Meter
- Data usage accessible through Wi-Fi
- Friendly User Interface (Android Application)

Relevant Standards

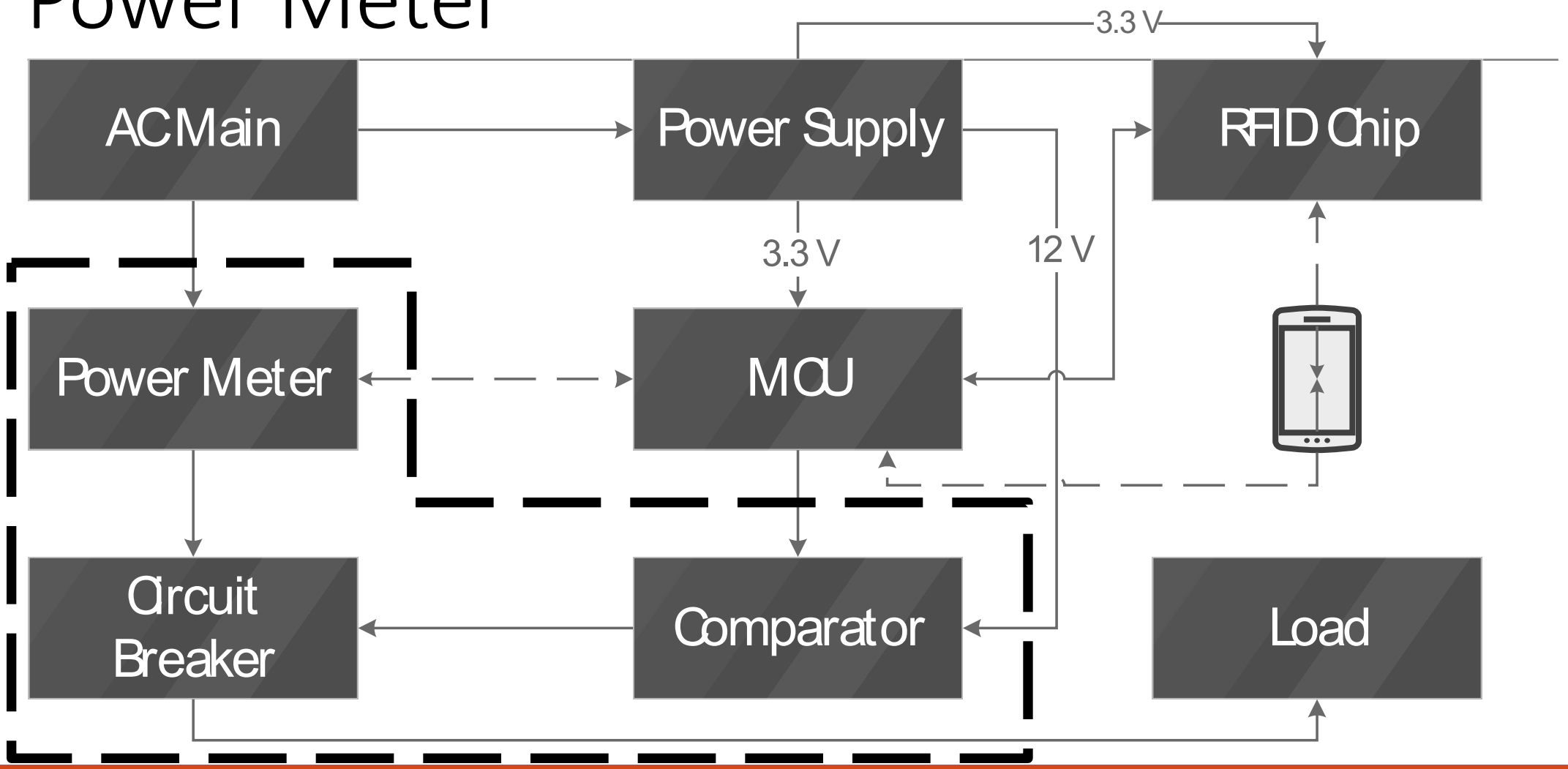
- Wi-Fi
  - IEEE 802.11 b/g/n
  - WPA/WPA2/WEP
- RFID/NFC
  - ISO-14443A
  - ISO-14443B
  - ISO-15693
  - FeliCa

Block Diagram



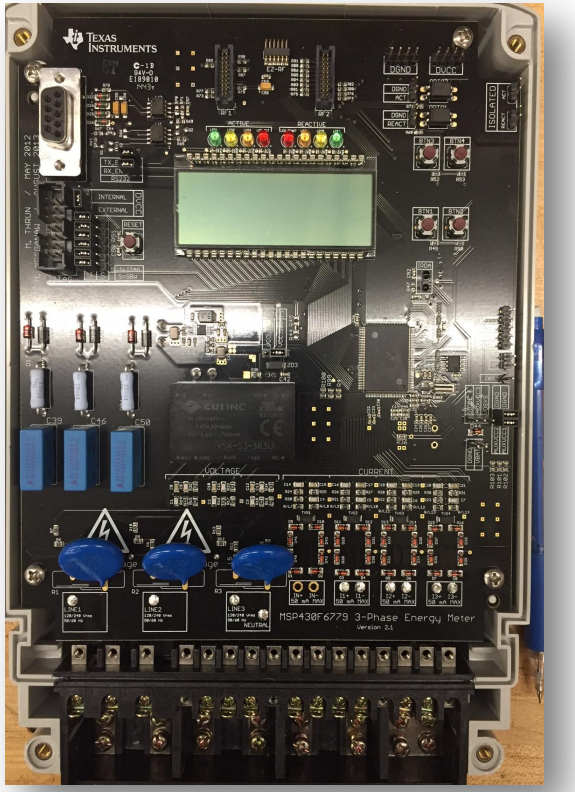
Design and Implementation

Power Meter


3.3 V
AC Main
Power Supply
RFID Chip
3.3 V
12 V
Power Meter
MCU
Circuit Breaker
Comparator
Load

EVM430-F6779 - 3 Phase Electronic Power Meter

- Run real-time electricity metering applications
- Provide AC power measurements for up to 3 phase
- GUI for calibration, measurement display, etc
- RS-232 interface for external communication
- 160 segment LCD display
- Supports Wi-Fi and ZigBee

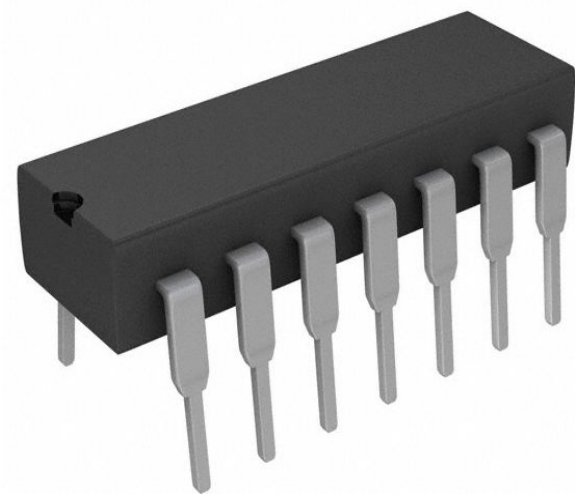


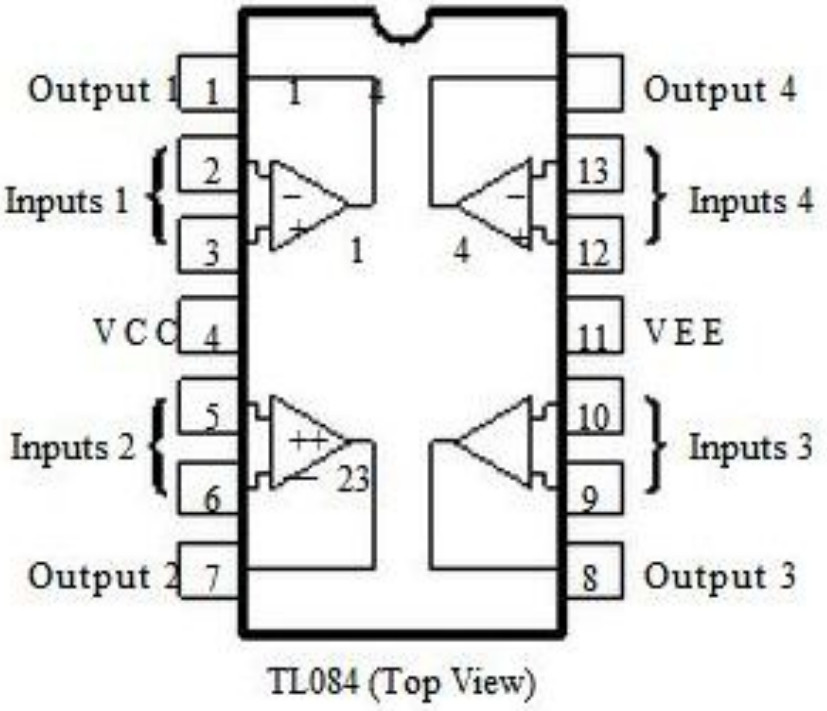
Solid State Relay

- Load current 75 A
- Input:
  - Input DC control 3-32 V
  - Trigger current 7.5mA/12 V
- Output:
  - Operating voltage 90-480V
  - Weight: 125g

Comparator TL084

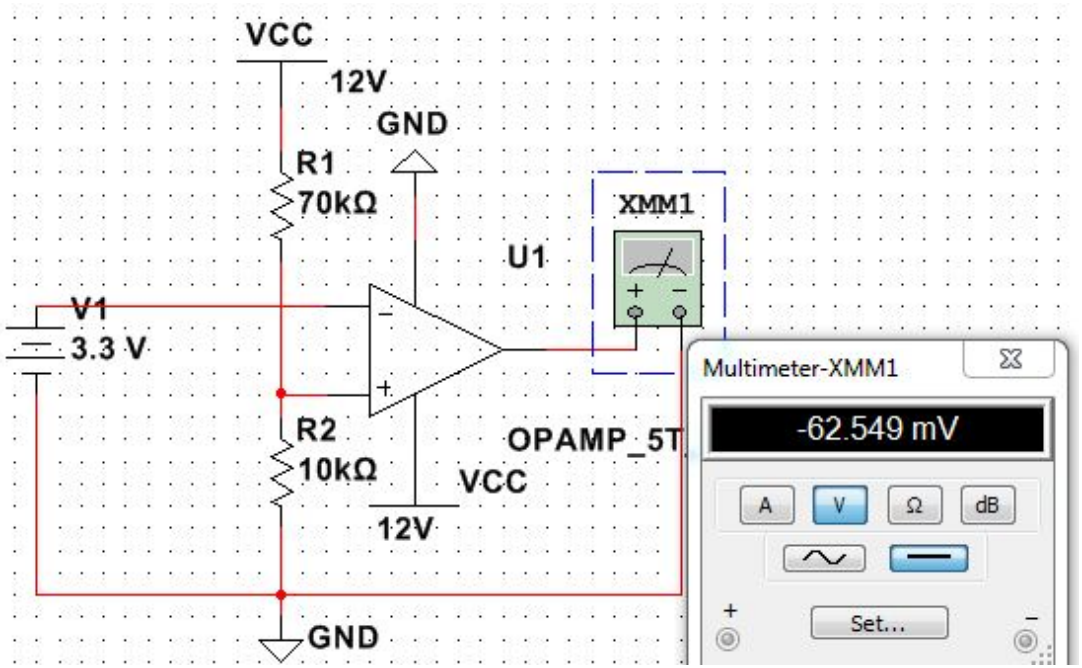
- MCU Output voltage 3.3
- Raise the voltage to 12 V.
- Using as a logic circuit either 0 to 12 volt output.



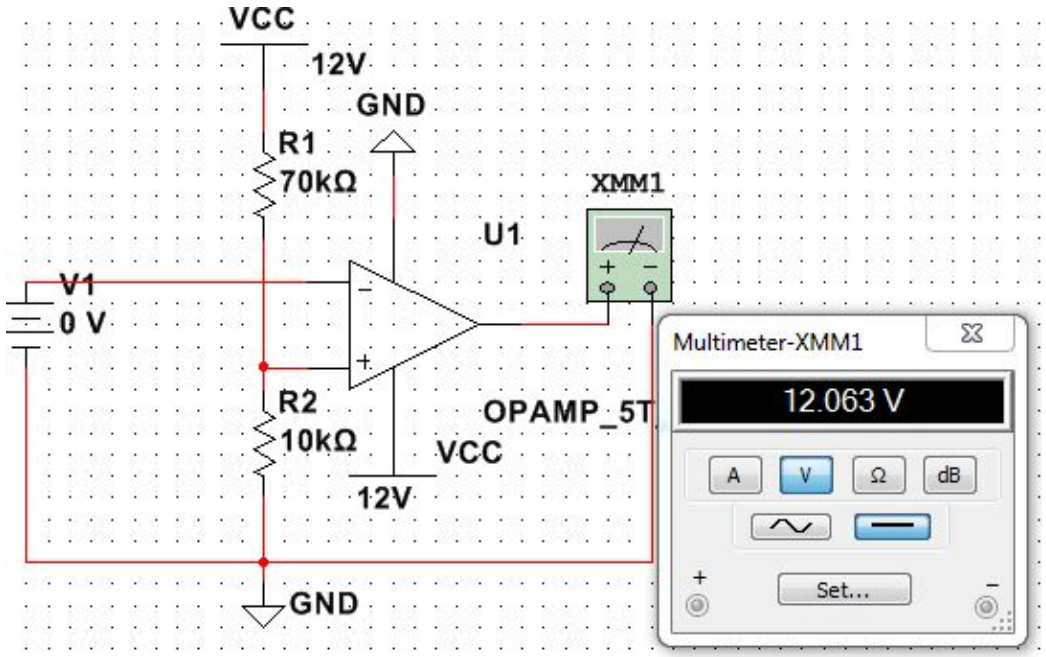


Comparator Logic Circuit

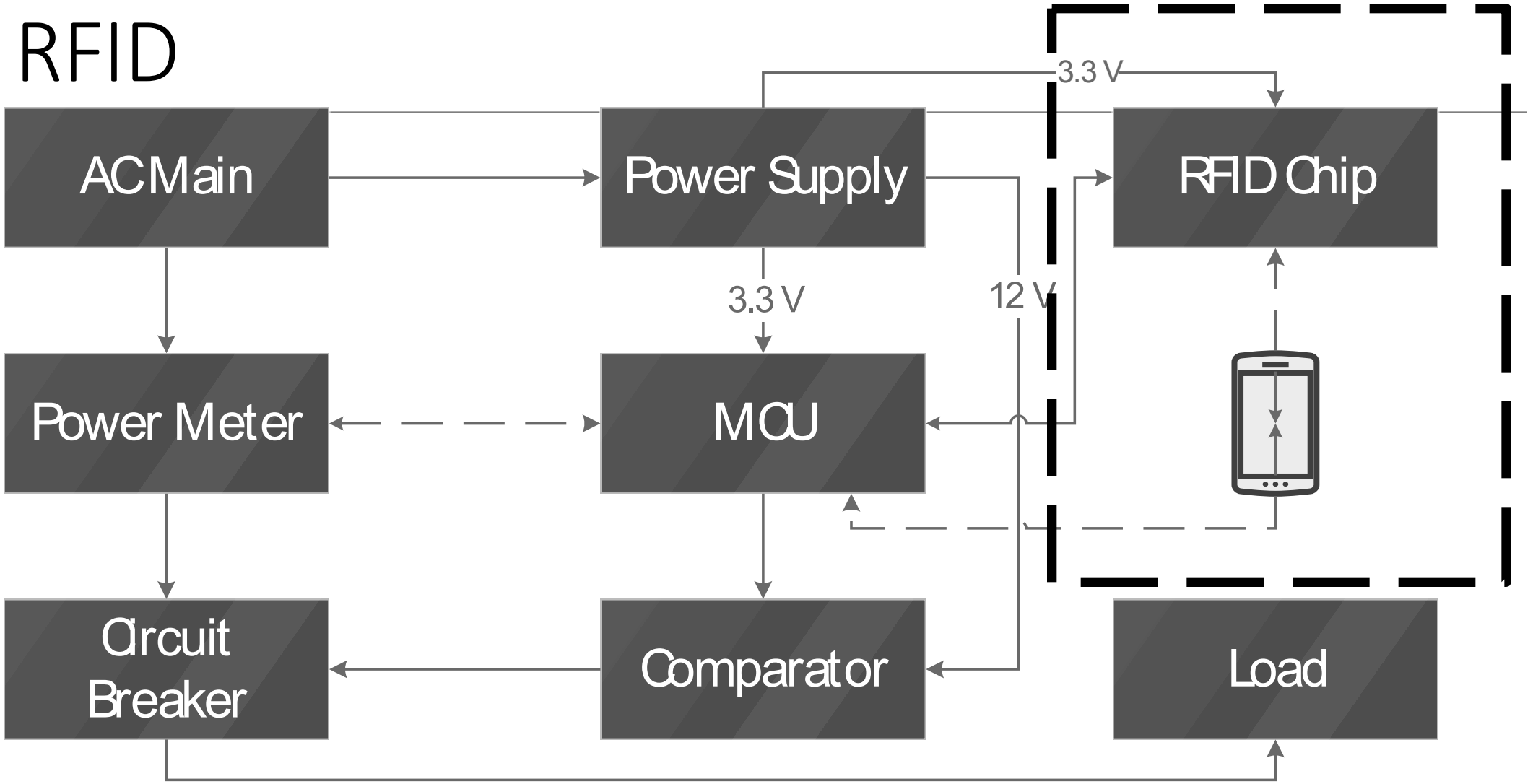
@3.3V INPUT OUTPUT LESS THAN 0



@0V INPUT OUTPUT 12 V



RFID


AC Main
Power Supply
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3.3 V
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Power Meter
MCU
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Comparator
Load

RFID

- NFC is chosen since near field communication is more secure
- Operates at 13.56 MHz
- Contains two separate parts: the Host and the Tag
- Used for payments

RFID Transceiver - TRF7970A

- RFID/NFC Reader, NFC Peer, or in Card Emulation mode
- RF Field Detector for NFC Physical Collision Avoidance
- 13.56MHz HF RFID Reader/Writer
- Supports ISO 15693, 18000-3, 14443A/B, and FeliCa
- Operable at Full Power or Half Power (5 or 3.3 V)
- Ultra Low-Power System Design (Power Down <1 µA)
- Parallel or SPI Interface

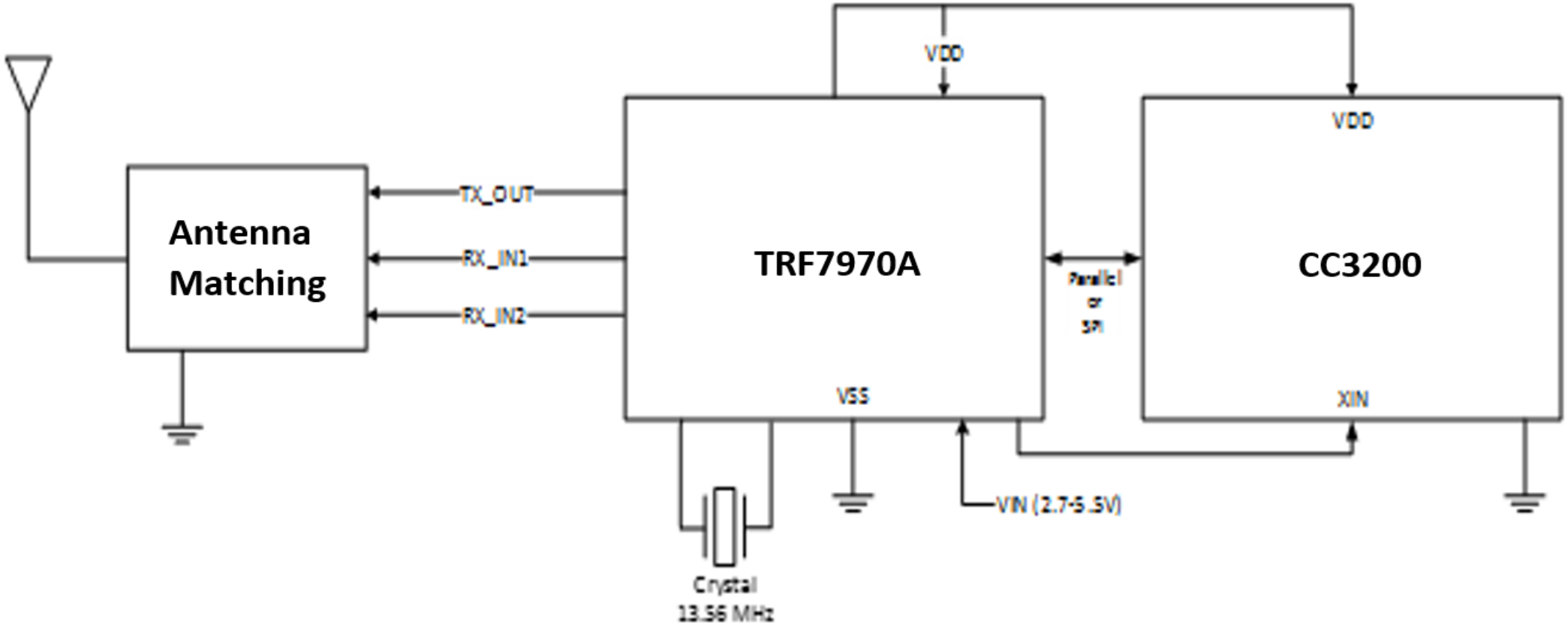
RFID BoosterPack - TRF7970ABP

- Compatible with NFCLink Library
- Compatible with CC3200 LaunchPad
- Supply Voltage 2.7 – 5.5 V
- 127 byte FIFO buffer
- 0.5 uA Power Down
- 2 mA Stand by Mode
- On-board Antenna
- Operational Power Supplied by LaunchPad

TRF7970A Operable Modes

Reader/Writer		Card Emulation		P2P	
Technology	Bitrate (kbps)	Technology	Bitrate (kbps)	Technology	Bitrate (kbps)
NFC-A/B (ISO14443A/B)	106,212, 424, 848	NFC-A/B	106	NFC-A	106
NFC-F (JIS: X6319-4)	212 , 424	N/A	N/A	NFC-F	212, 424

RFID & MCU Block Diagram



Phone Selection

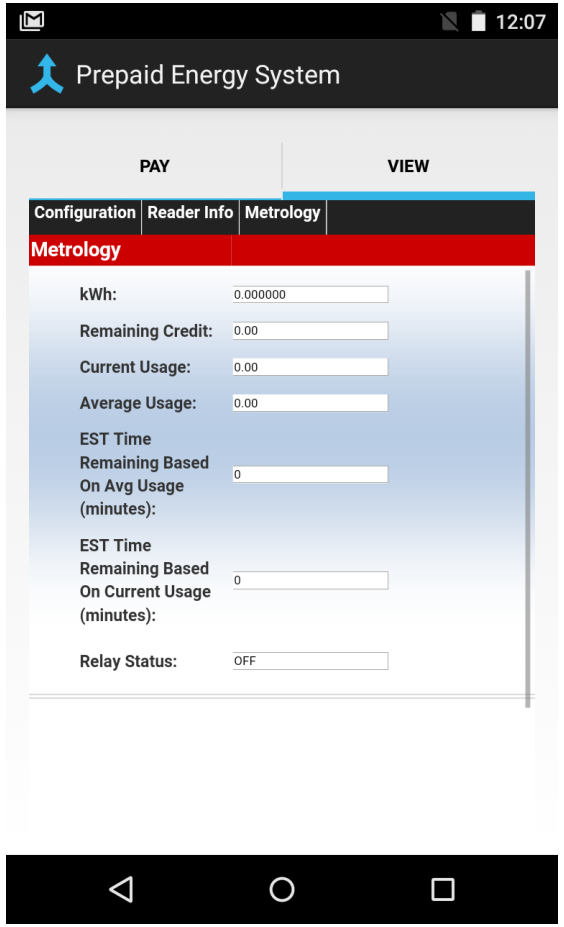
- Android – Open Source & NFC since 2008
- Nexus S & Nexus 4
- Nexus S was initially used because it was cheap
- Nexus 4 used because of Android 4.4
- Broadcom NFC chip, which emulates a Tag 4 Type ISO14443A
- Android 4.4 was the minimum OS for implementing Host Card Emulation which uses the NDEF protocol

NDEF

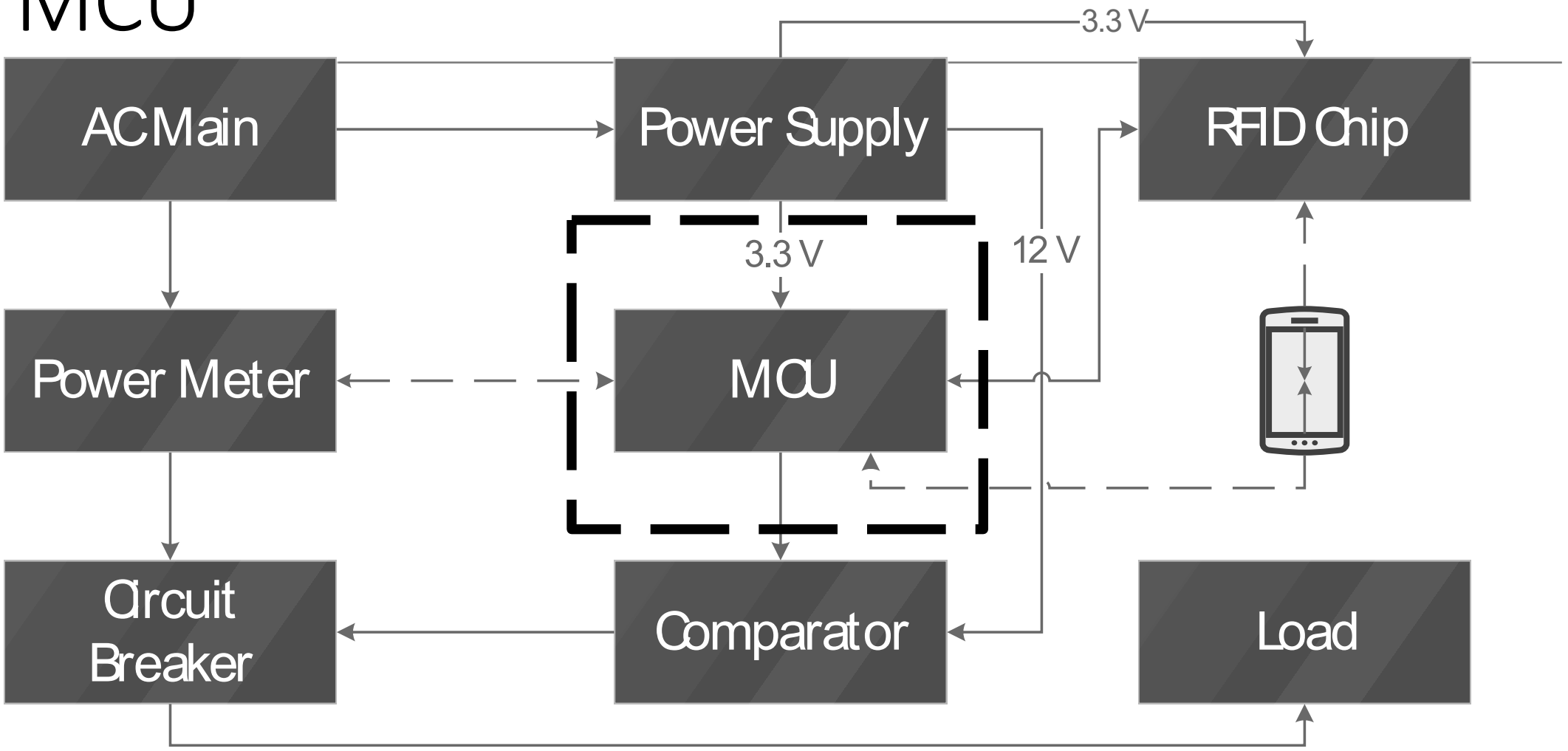
- NFC Forum Data Exchange Format is a lightweight binary message communication protocol
- NDEF Messages are the basic "transportation" mechanism for NDEF records. Each message can contain one or more records.
- NDEF Records contain a specific payload, and follow a specific structure that identifies the contents and size of the record.
- Since we are emulating Type 4 tags, APDU commands (like READ BINARY and STORE BINARY) are used to read and store NDEF data to complete the communication between the reader and the phone.
- A wait time extension request was being sent out by the phone. This had to be echoed by the RFID reader.

Android Application

- User Interface
- Mobile app will have alert system
- Emulating a transponder tag using HCE
- Emulate Android Pay
- Retrieve Data through Wi-Fi



MCU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Wireless Communication

Parameter	Bluetooth	ZigBee	Wi-Fi
Frequency	2.4 GHz	800-900 MHz, 2.4 GHz	2.4 GHz, 5 GHz
Range	10 m	10 - 100 m	Up to 100 m
Data Rate	1 Mbps	250kbps	54 Mbps
Power Consumption	Medium	Low	High
Implementation Complexity	Easy	Moderate	Difficult

Microcontroller Unit

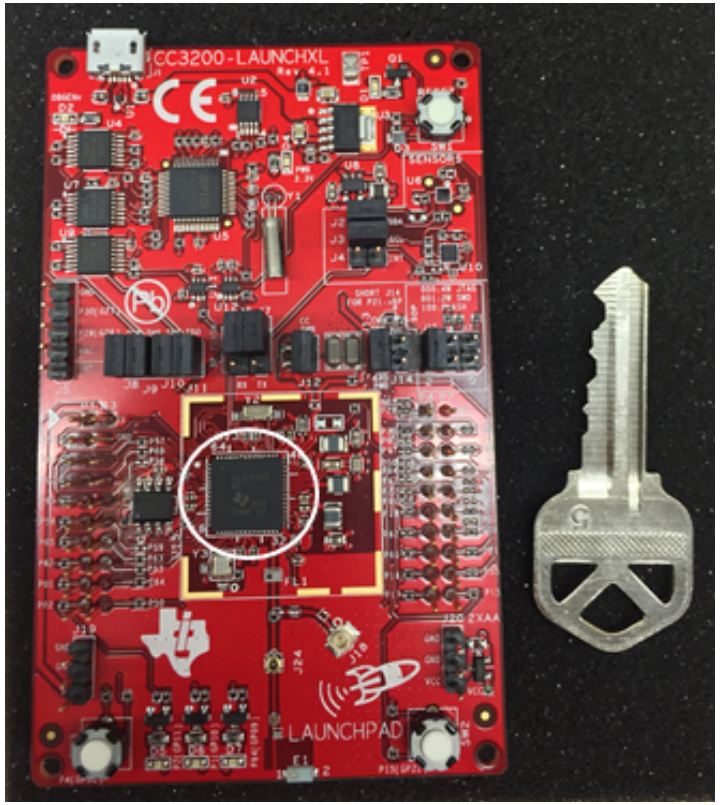
- CC3200 Wireless MCU
  - ARM Cortex-M4 CPU at 80 MHz
  - Integrated Network Processor
  - SimpleLink Library
  - 4 Low-Power Modes

9mm x 9mm

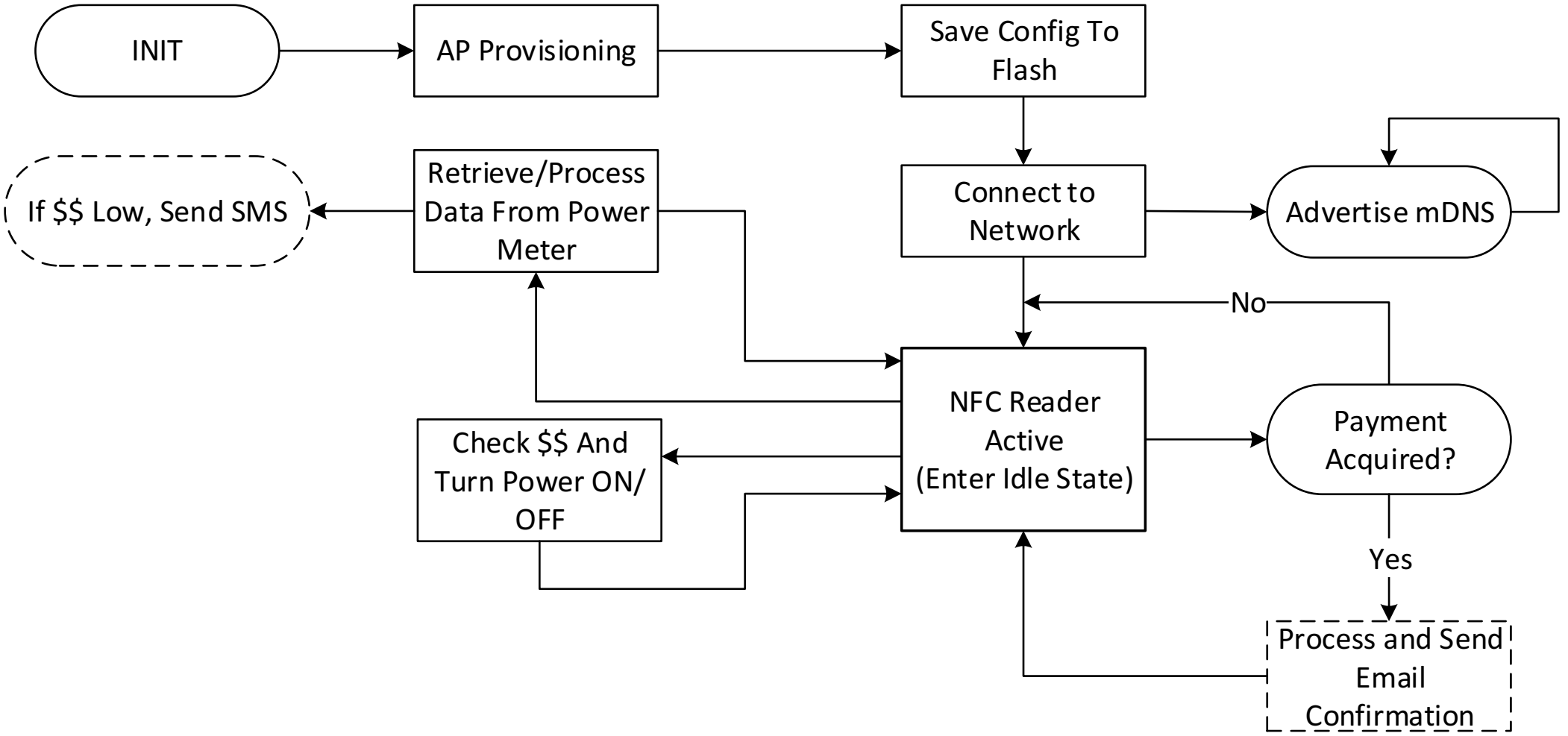
Microcontroller Unit: Prototyping

CC3200 LaunchPad

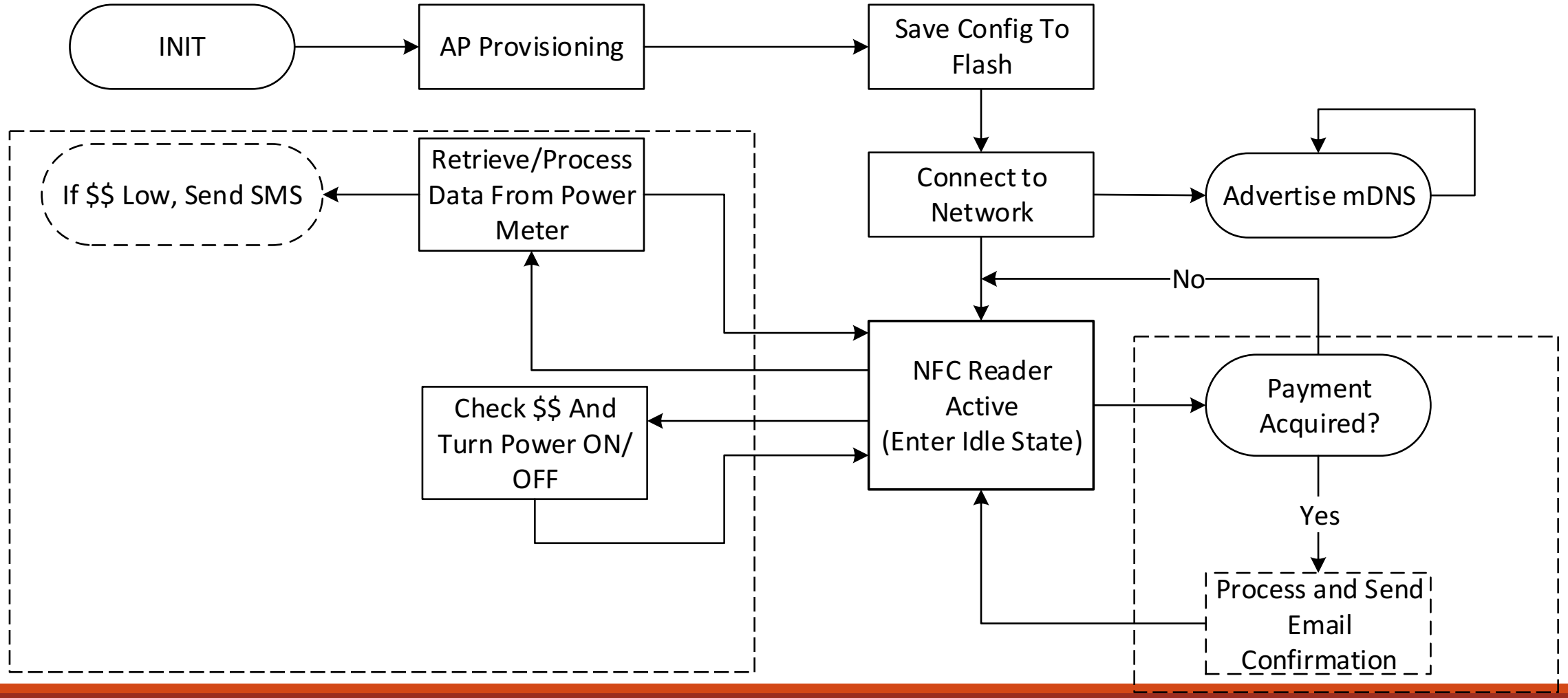
- On-board Antenna
- BoosterPack Headers
- Powered From USB
- JTAG/FTDI



Process Flow Diagram

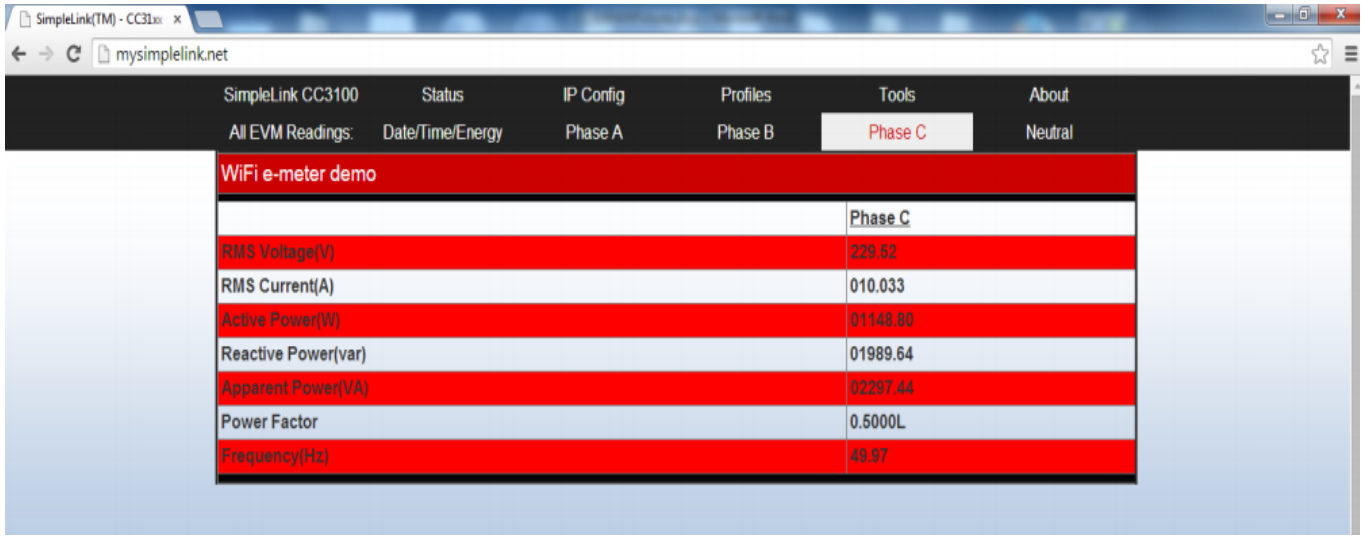


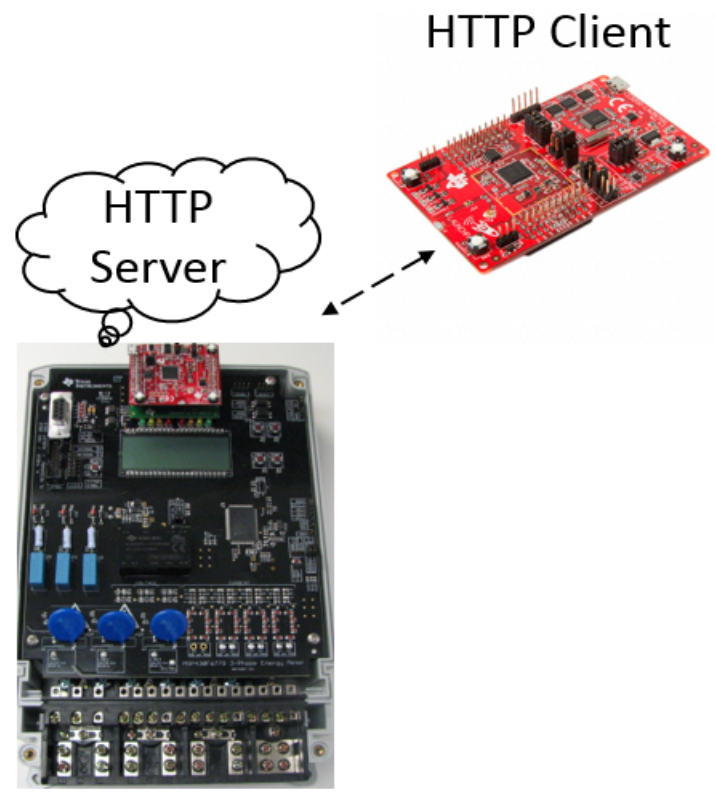
Process Flow Diagram



Wi-Fi: Power Meter

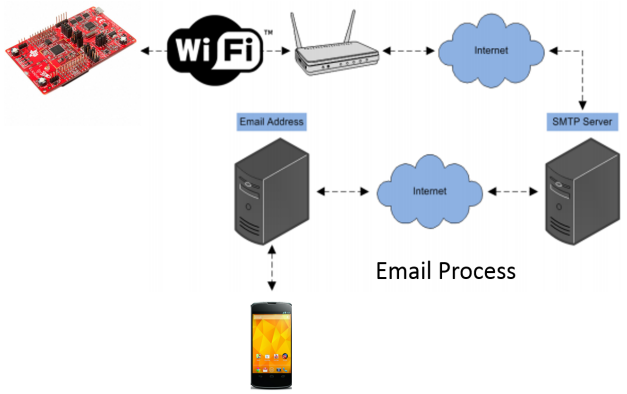
- CC3100 on power meter hosts HTTP web server
- CC3200 acts as HTTP Client



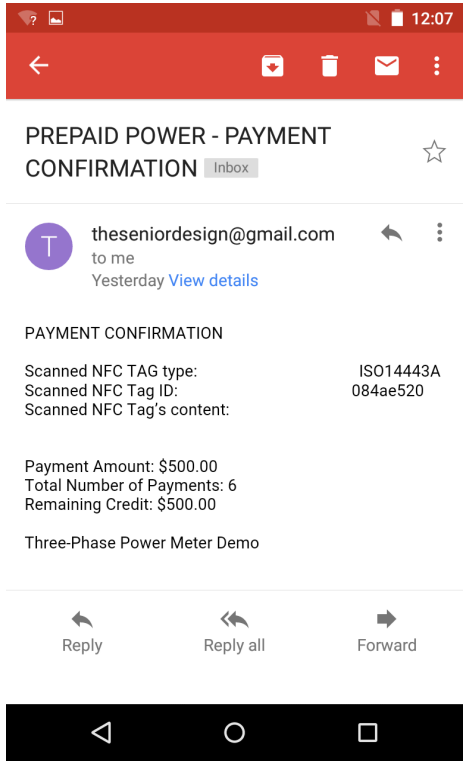


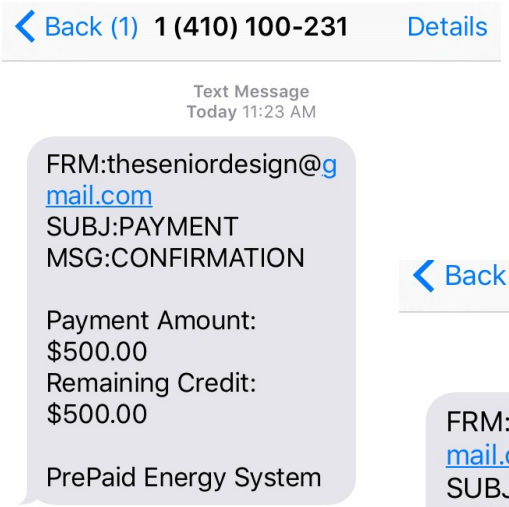
Wi-Fi: Phone

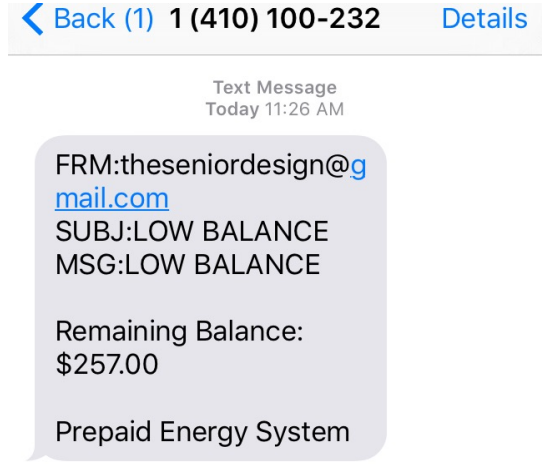
- mDNS broadcasts to phone
- Sends payment confirmation and alert to email and phone



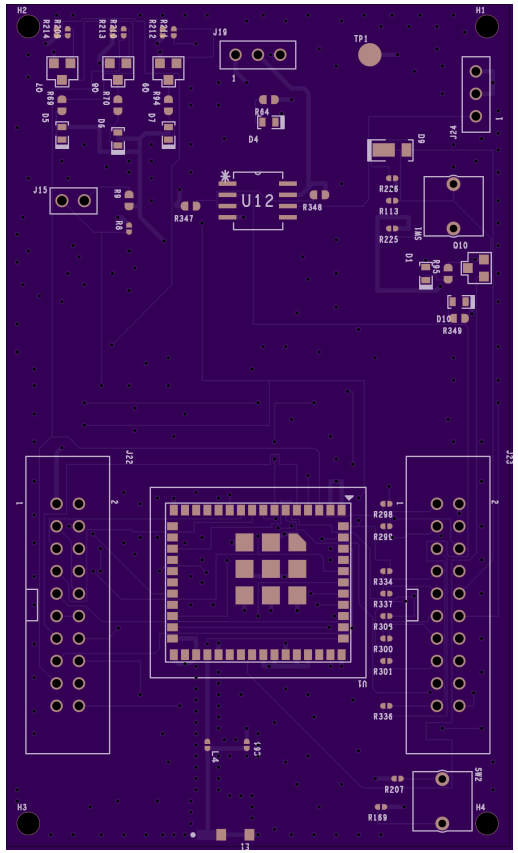
Email Process

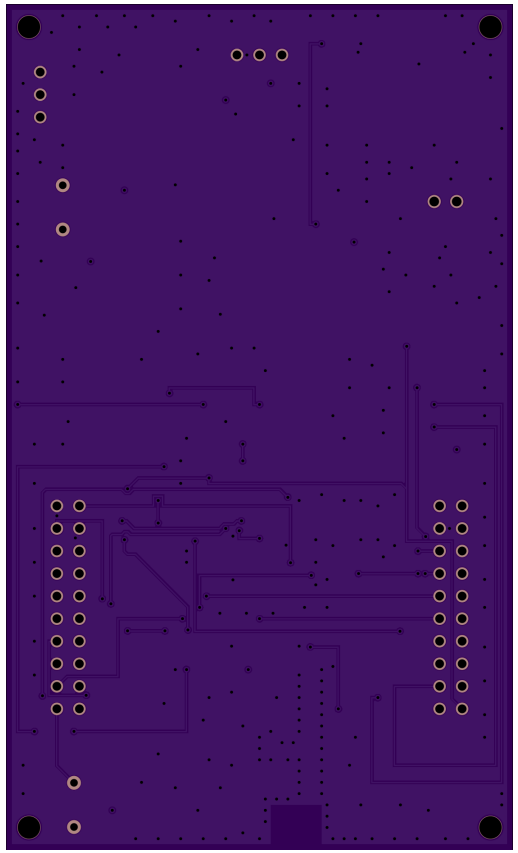




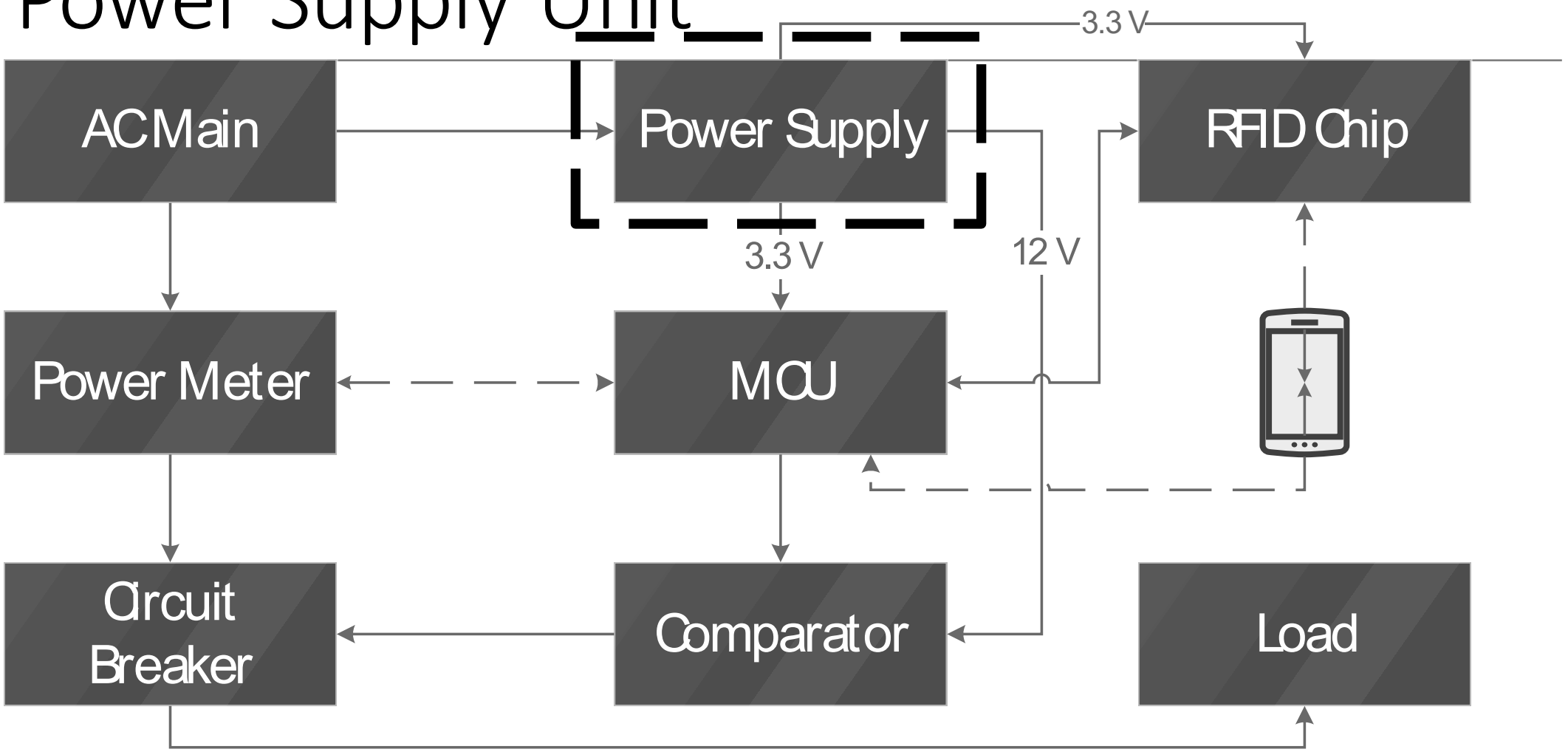


PCB

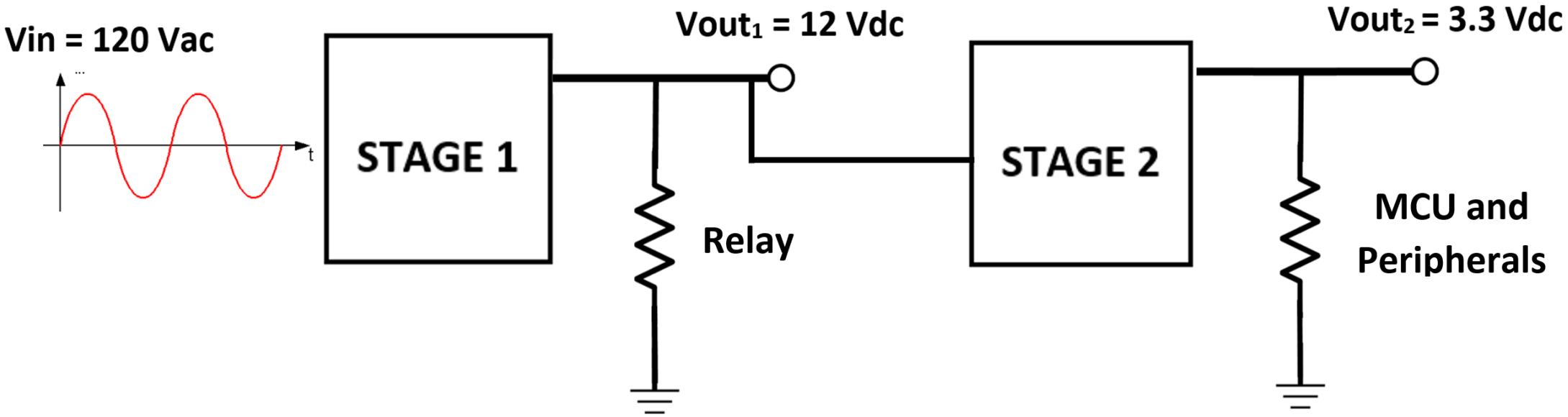




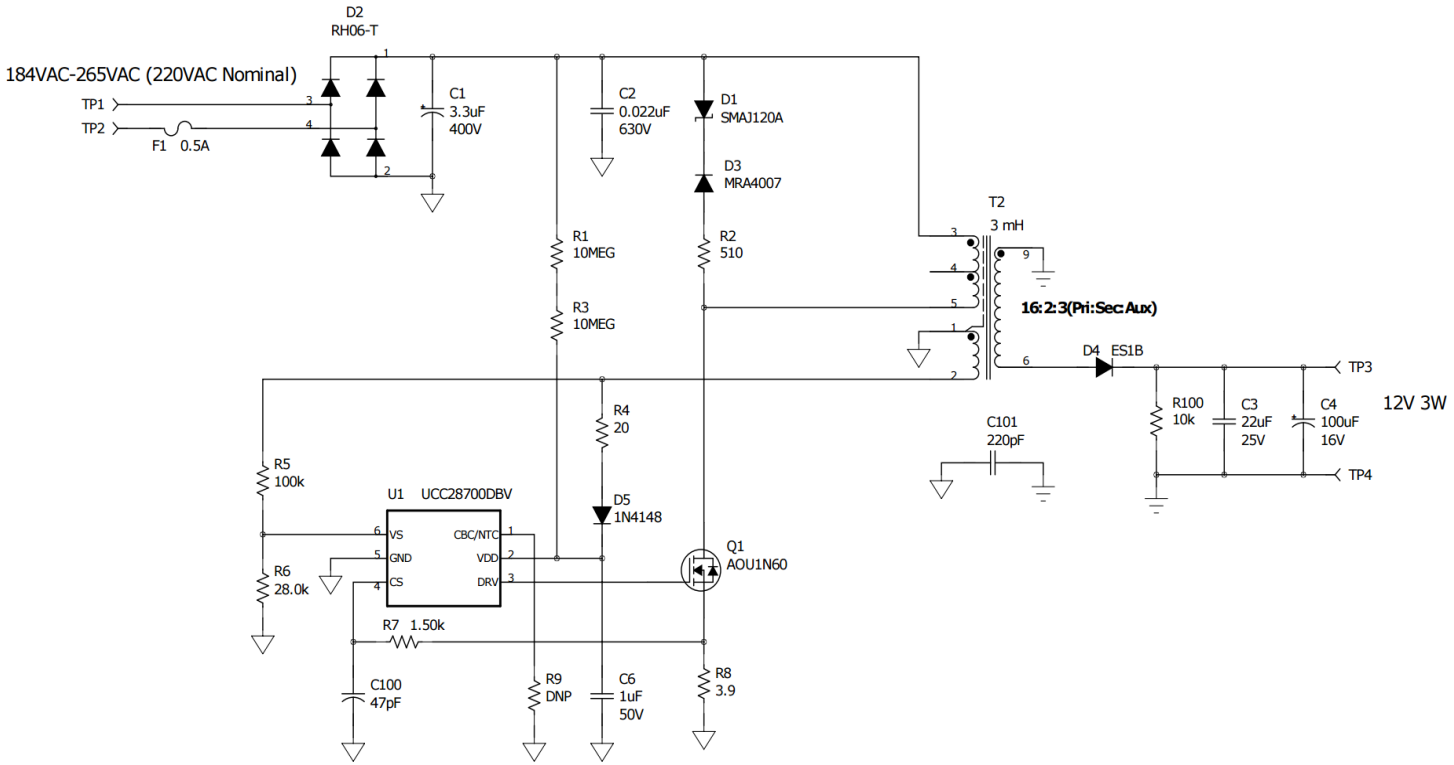
Power Supply Unit



Power Supply Design



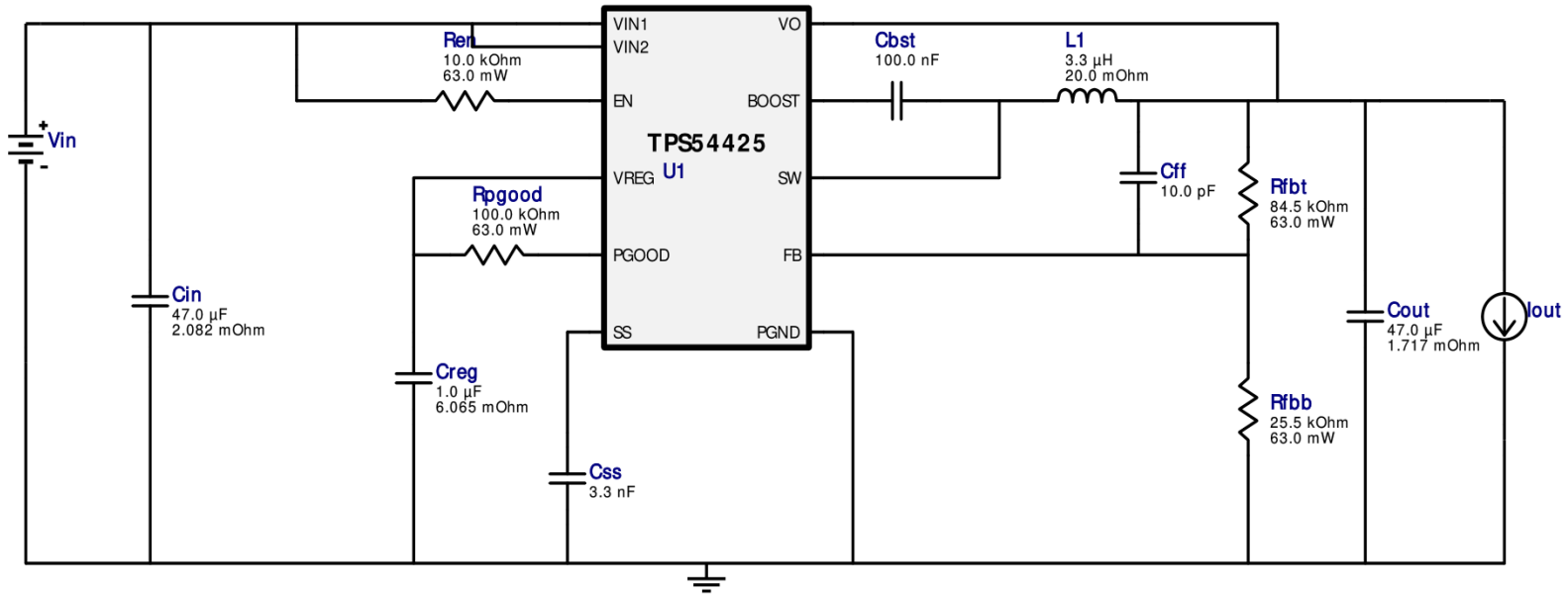
120 V AC to 12 V DC (Stage 1)



Design : PMP8764

VinMin = 110.0V
VinMax = 130.0V
Vout = 12.0V
Iout = 1.0A
Device = PMP8764
Topology = Flyback
BOM Count = 35
Total Pd = 1.25W

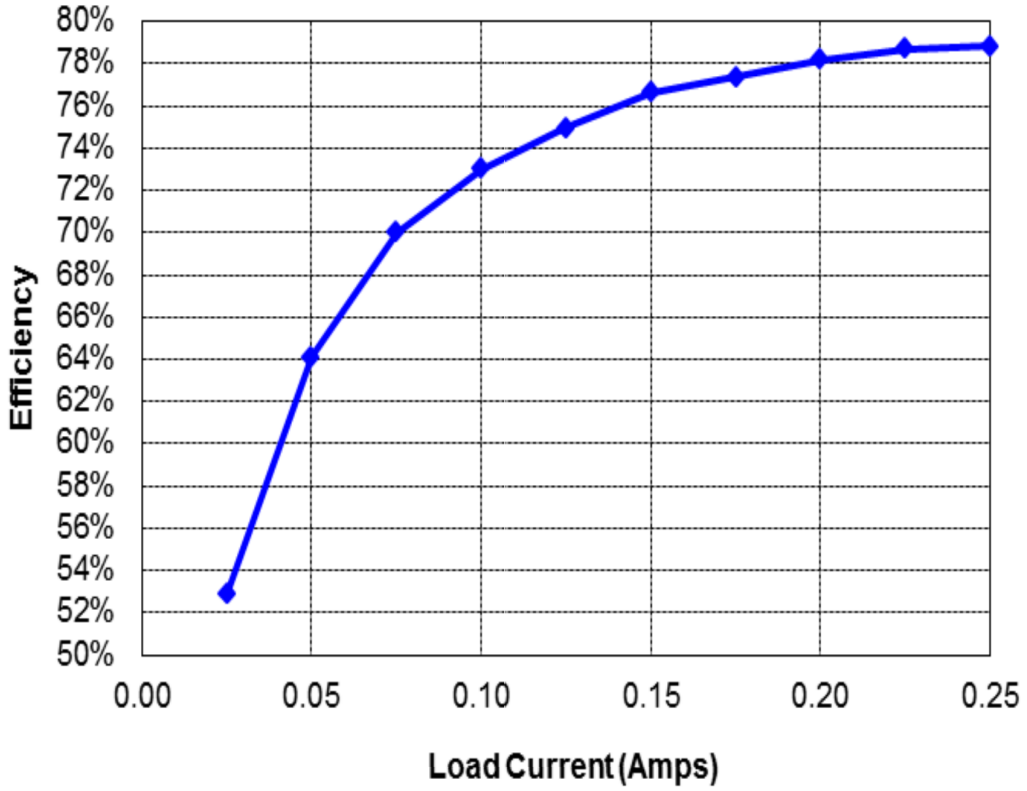
12 V DC to 3.3 V DC (Stage 2)



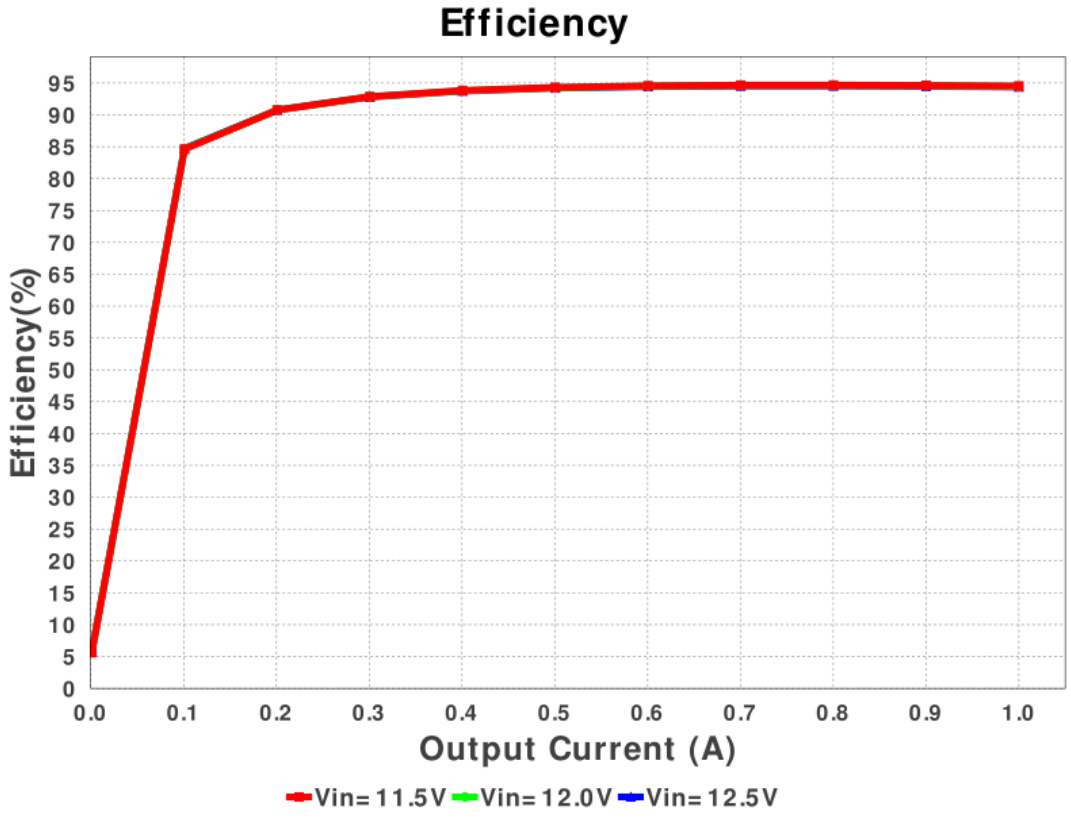
Design : 4550765/86
TPS54425PWPR

VinMin = 11.5V
VinMax = 12.5V
Vout = 3.3V
Iout = 1.0A
Device = TPS54425PWPR
Topology = Buck
BOM Cost = $2.21
BOM Count = 12
Total Pd = 0.21W

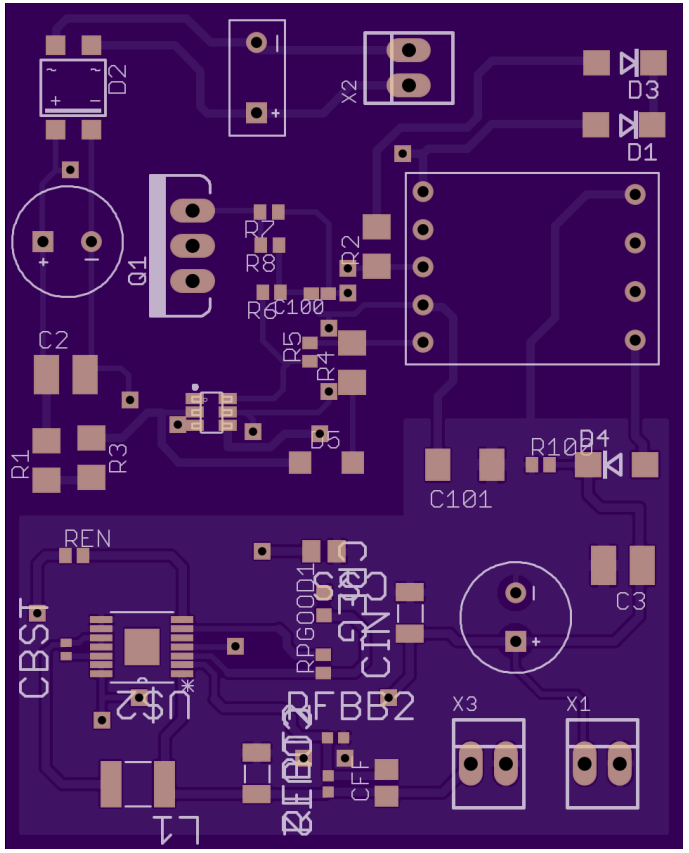
Stage 1

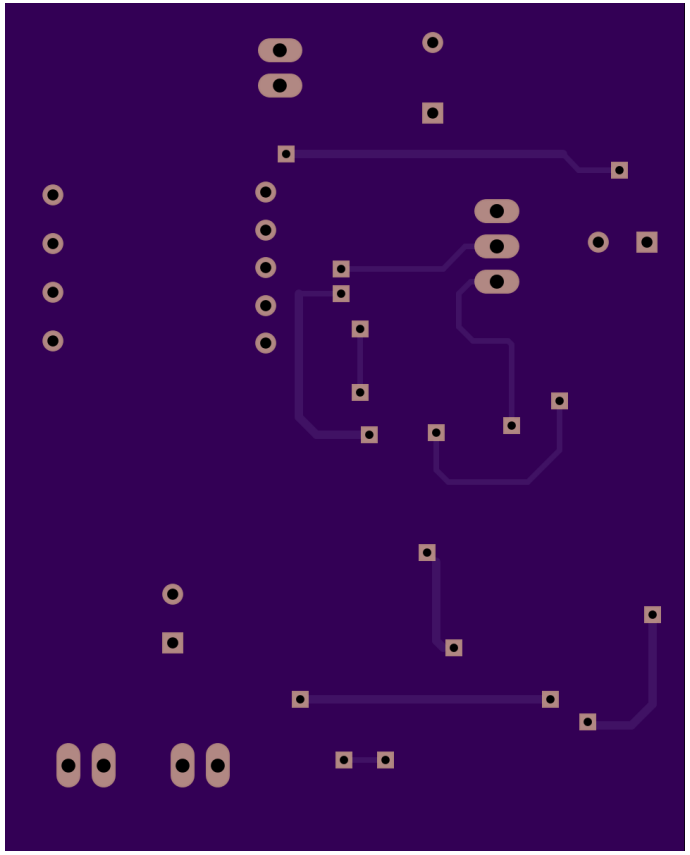


Stage 2

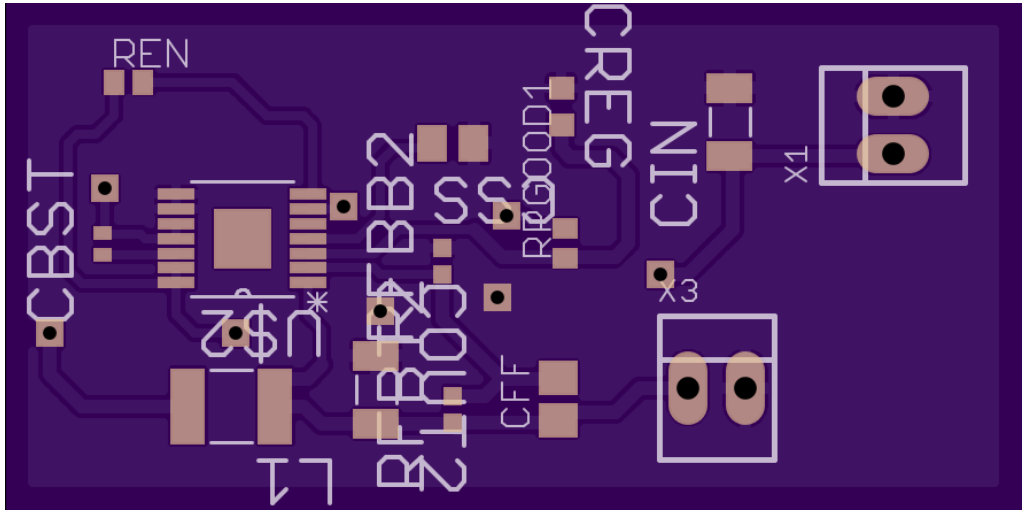


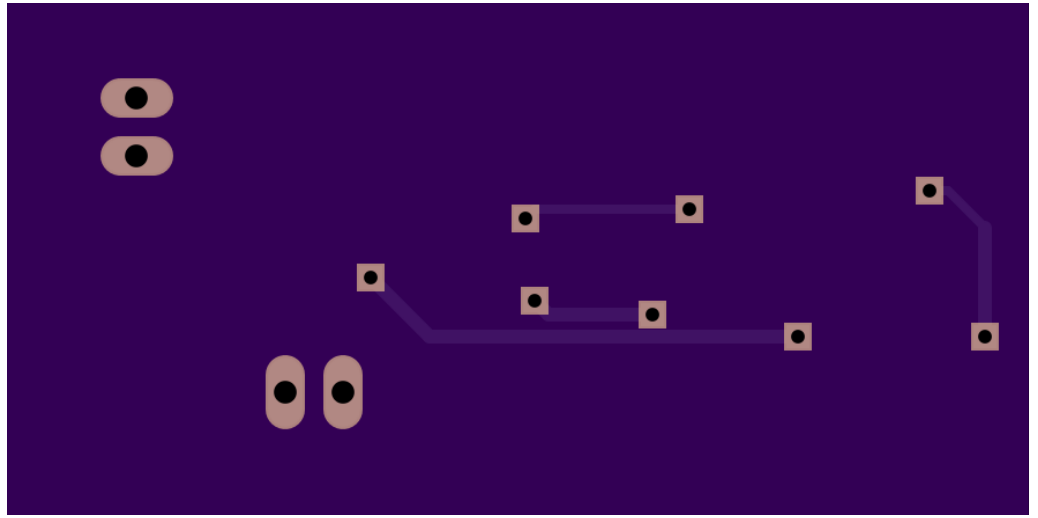
PCB


D2
X2
D3
D1
Q1
R7
R8
R6
C100
R2
R5
R4
C2
R1
R3
D5
R100
D4
C101
REN
CBST
RPGOOD1
C3
X3
X1
L1



PCB DC to DC





Administrative Content

Responsibilities

Youssef Ojeil	Michael Cuervo	Sahin Okur	MD. Rahaman
Android Application	Power Supply	Microcontroller	Power Meter
RFID	PCB Design	Wi-Fi Communication	Relay

Facilities and Equipment

- University of Central Florida (UCF) Smart Lab
- UCF Senior Design Lab
- Texas Instruments Innovation Lab
- Three-phase power outlet found in Engineering 1, Room 456

Budget

* Parts provided free of charge by sponsor

Part	Supplier	Quantity	Cost
CC3200 LaunchPad	Texas Instruments	1	$29.99*
TRF7970A BoosterPack	Texas Instruments	2	$25.00*
CC3100 BoosterPack	Texas Instruments	2	$19.99*
EVM 430-F6779	Texas Instruments	1	$299.00*
SSR-75DAH	Fotek	1	$10.00
Nexus 4	LG	1	$80.00
Senior Design Paper	The SPOT	1	$13.00
PCB	OSH Park	3	$140.00
Power Supply PCB	OSH Park	6	$234.00
Miscellaneous			$100.00
Total			

Limitations

- Currently supports only single phase measurements
- No authentication method for card payments
- User must be connected to Wi-Fi network to access data
- System does not support all modes of NFC
- Mobile App does not support official merchant/buyer system. Can further be improved by using Android Pay APIs.

Questions?