Group 4: Pocket Amp

Trent Coleman, EE
Joshua DeBaere, EE
Marissa Kane, EE
William McKenna, CpE

Motivation

- Portability
- Affordability
- Passing Senior Design

Goals of the Pocket Amp

- Quality of Sound
- Battery Life
- Ease of Use

Requirements Overview

ID	Type	Requirement
E.1	External	1-hour battery life
E.2	External	Fit in a 5x6x3 inch pocket
E.3	External	Weigh less than 5lb
E.4	External	Have a 6.35mm “phone jack” audio input jack
E.5	External	Have a 3.5mm “mini phone jack” audio output jack
E.6	External	Will NOT have an onboard speaker
E.7	External	Will have an external charging port to charge the battery
I.1	Internal	Power a pair of headphones
I.2	Internal	Use an onboard MSP432 MCU to handle digital signal processing
I.3	Internal	Use MSP432 built-in ADC
I.4	Internal	Amplify the standard range of guitar and bass guitar sounds
I.5	Internal	Sample at least 12-bits with a frequency of at least 30kHz
I.6	Internal	Introduce less than 1% total harmonic distortion
F.1	Effects	Implement digital delay effects
F.2	Effects	Implement digital reverb effects
F.3	Effects	Implement digital echo effects
F.4	Effects	Implement digital flanger effects
F.5	Effects	Implement digital chorus effects
F.6	Effects	Implement analog distortion effects
F.7	Effects	Implement analog overdrive effects
F.8	Effects	Implement analog tone control
F.9	Effects	Implement analog volume control
U.1	UI	Communicate through Bluetooth with smartphone application
U.2	UI	App will be developed for Android devices
U.3	UI	App will control effects
U.4	UI	App will control volume
A.1	Admin	Unit production hardware cost will be less than $100
A.2	Admin	Unit prototype will be finished by the end of Spring 2017

Current Tech: Guitar Amps

Modelling Amps
- Large variety
- Mimics vacuum tube amplifiers

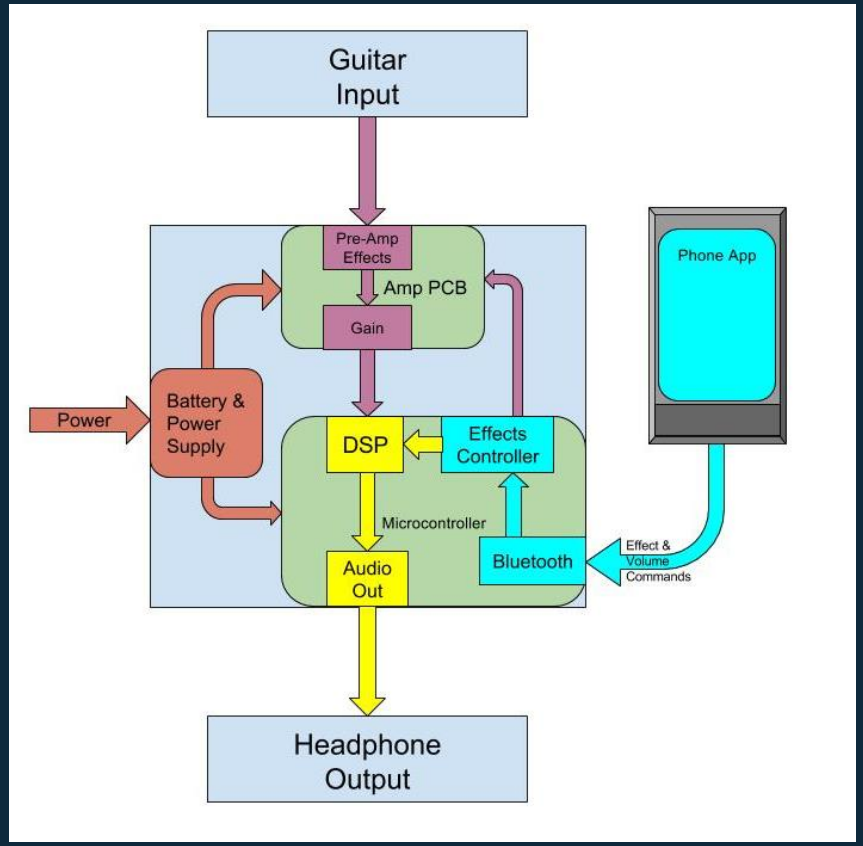
Portable Amps
- Increased mobility
- Less play-time
- Most power drives speaker

Traditional Amplifiers
- Wide range of effects
- No power constraints
- No size constraints

Current Tech: Phone Apps

- Digital implementation of traditionally analog effects
- Requires a converter to plug guitar into phone (usually $20 - $99)
- Latency of app-converter

High Level Block Diagram

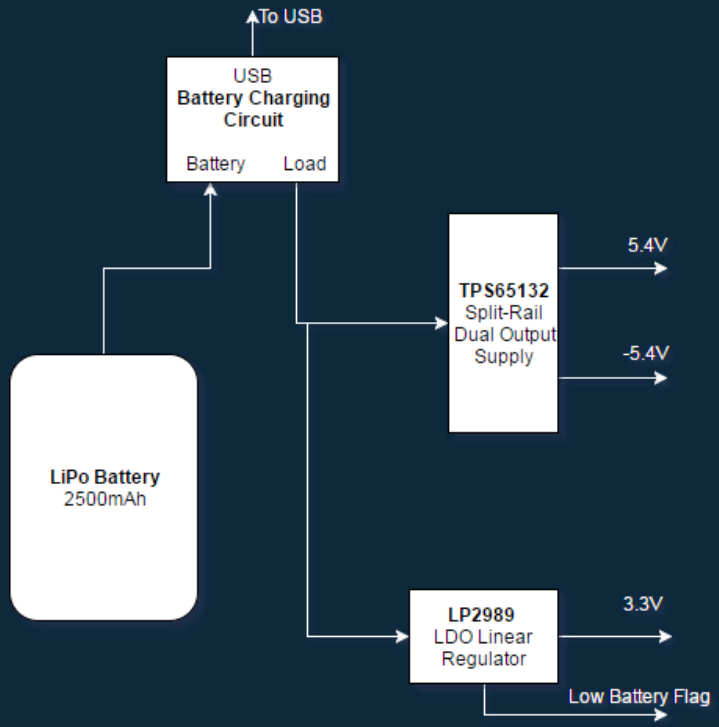


1 Power System

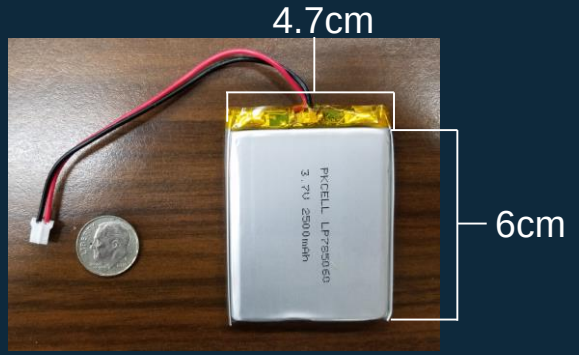
Power System Goals

- Provide a compact, safe and sufficient power source for the Pocket-Amp
- Provide desired voltage and current levels to the analog and digital components of the Pocket-Amp.
- Perform charge management of the energy storage system

Power System Block Diagram



Power System Components



Battery

- With recent advances in batteries, there are many compact battery systems available.
- Lithium Ion Polymer (LiPo) was chosen for this project
- Provides a high nominal voltage of 3.7V and high energy density.
- The LiPo is able to be packaged in a rectangular case and thus able to fit better with the rest of the components.

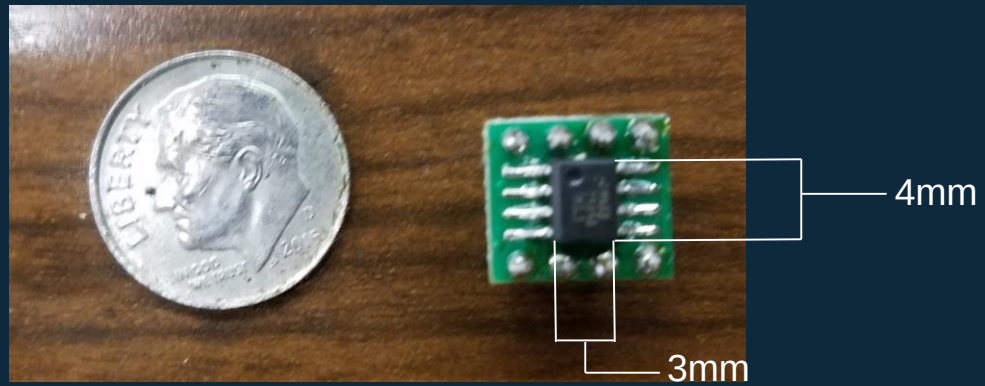
Power System Components

Digital Voltage Conversion

- Two primary options for lowering the battery voltage for the digital devices
- Buck Regulator- higher efficiency through a wider range of inputs but utilizes inductors
- LDO linear regulators – high efficiency when the input is closer to the output, smaller simpler device and does not utilize an inductor.

Power System Components

LP2989- A LDO linear regulator produced by TI. This regulator is used for the digital supply as it will output 3.3V. It also outputs an error flag when the input reaches 5% of the desired output voltage. This will be fed to the microcontroller to create a low battery signal.



Power System Components

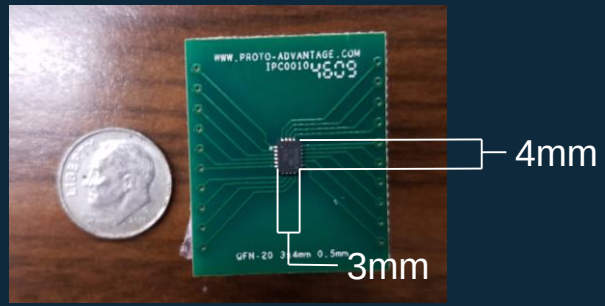
Analog Voltage Conversion

- A higher voltage would be required as well as an inverted supply
- Several possible designs were considered
- Utilizing a single boost convertor in conjunction with a separate inverting boost convertor
- Creating the appropriate voltage through a boost convertor and then utilizing a buck convertor as a simple inverter
- Split-rail single inductor convertor to provide both positive and negative voltages

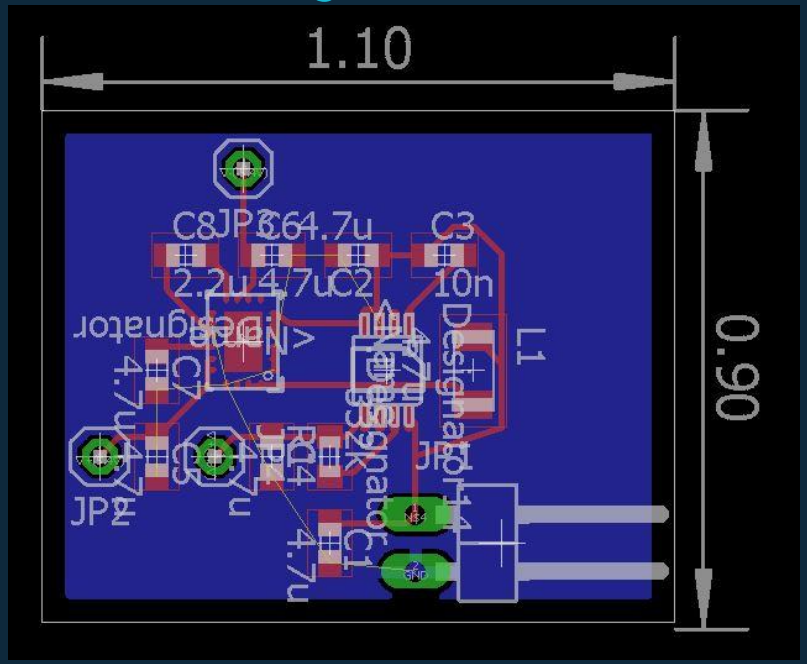
Power System Components

Analog Voltage Conversion

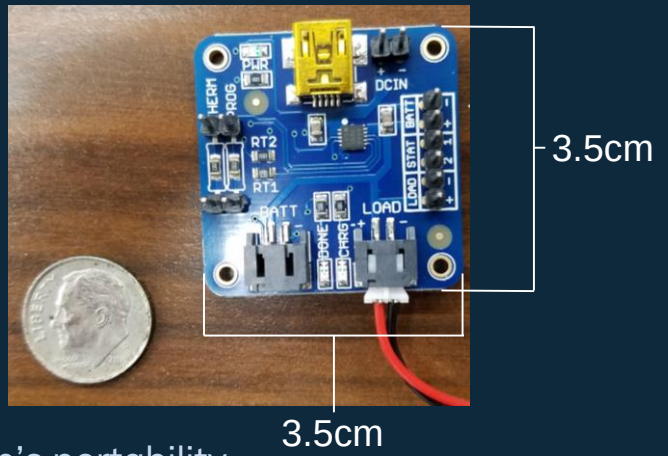
TPS65132 – A single inductor Split-rail boosting convertor. This convertor will supply both negative and positive voltages for the analog components. Limiting the analog power supply to a single inductor and single chip reduces space on the PCB and also limits any noise that might be produced through the windings of the inductor.



Power System PCB Layout



Power System Components



Battery Charging Schemes

- Battery charging is an essential par of the Pocket Amp's portability
- Charging can be the most expensive and risky part of the power system
- Failure with a battery charging scheme can be an expensive/ dangerous failure
- A prebuilt charging scheme based on the MCP73833 was purchased to help guarantee safe charging

2 Analog System

Analog System Overview

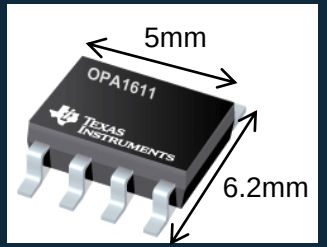
Effects
Realization of effects commonly found in professional sound systems.

Amplification
Linearly amplify guitar input of approximately 100mV - 1V to ADC input of 0V – 3.3V

Equalization
Three channel, digitally controlled equalization of input signals that can be tuned to personal preferences

Filtering
Ensuring only frequencies in the range of the electric guitar will be amplified to improve efficiency and sound quality

Op-Amp Selection



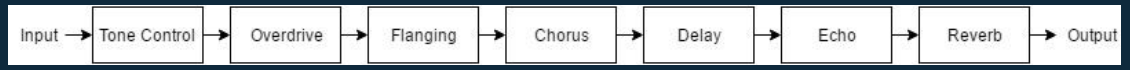
Amplifier	Pros	Cons
LME49723	Inexpensive	Noisy, Low slew Rate
OPA1611	Good all around performance	Not exceptional at anything
OPA1632	High GBWP, very low noise	Expensive, High offset voltage

Analog Effects

- Equalization
  - Shaping the output response to produce the wanted sound signature
- Overdrive
  - A common effect in genres like blues and rock

All analog effects use the OPA1611 op-amps.

Effects Diagram



Order of effects chosen by effect on signal power.

Input Filtering

- 60Hz Hum

Inductance caused by mains electric

- Pass >80Hz with minimal attenuation
- Attenuate 60Hz and lower by at least 3 dB

Filter Types

Passive Filters
3dB drop at 60Hz

Doesn’t return close to 0dB until near 500Hz

Sallen-Key
Active notch filter

Extremely high sensitivity at required Q factor

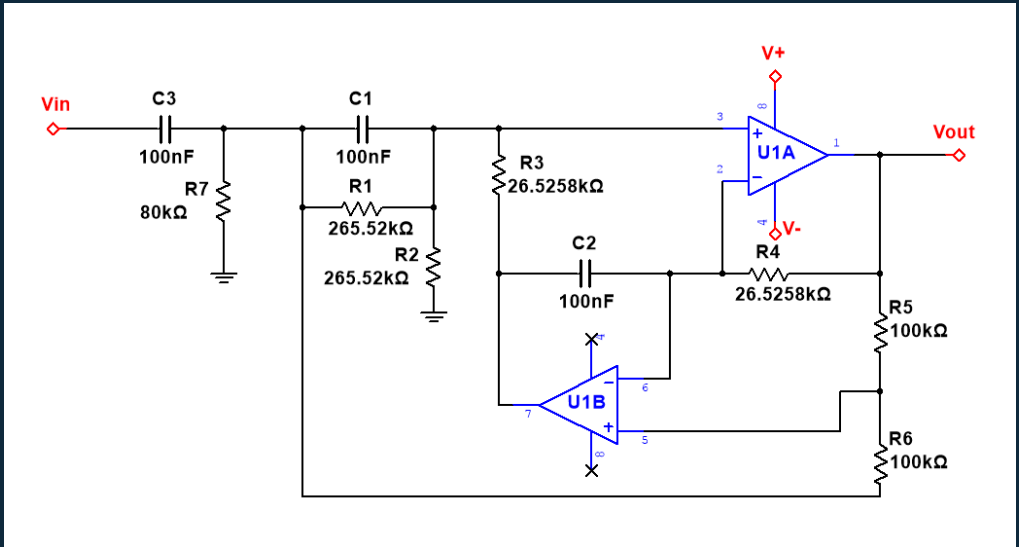
Would require variable resistance to tune

Fleige
Active notch filter

Requires two op-amps in addition to a low-pass filter

Dramatic reduction in 60Hz with little attenuation above 80Hz

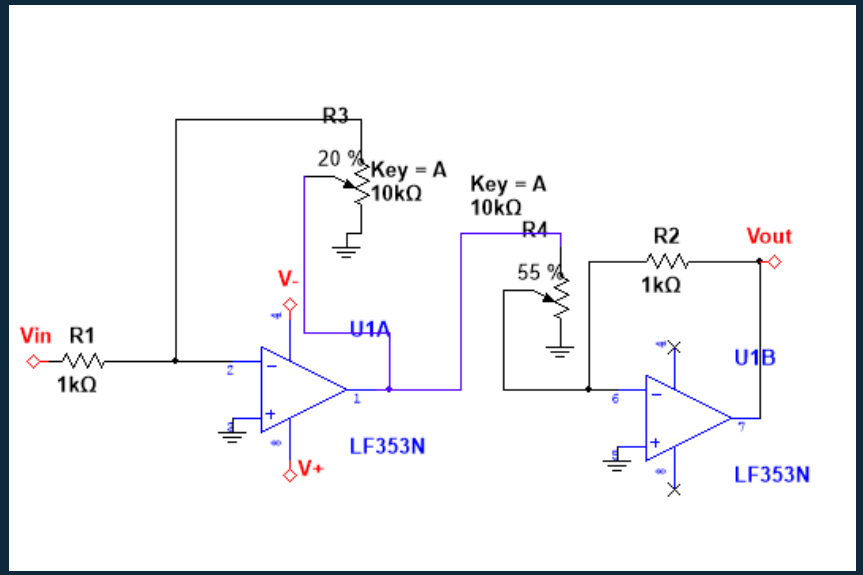
Fliege Filter Topology



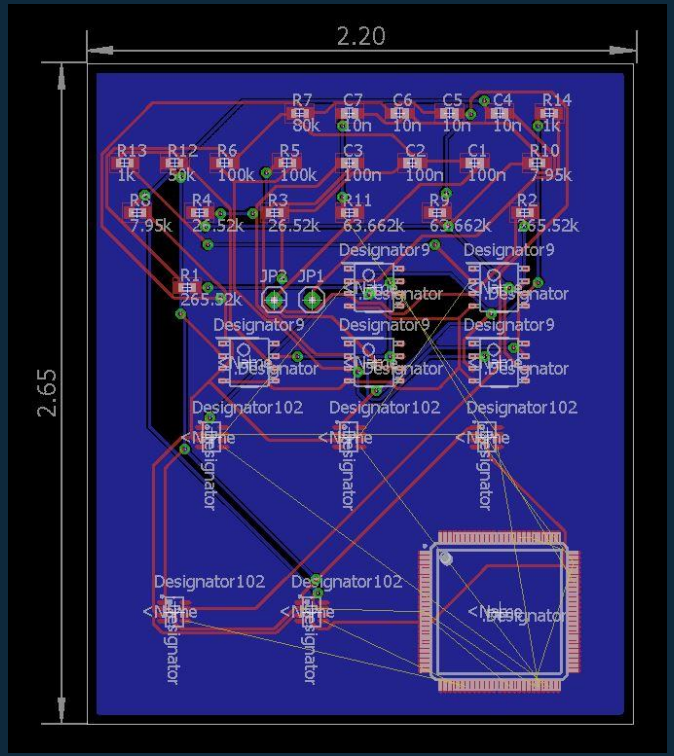
Overdrive

- Methods
  - Driving Tube amplifier into overdrive region
  - Driving a solid state amplifier to it's rails
  - Clipping network

Overdrive


R3
20 %
Key = A
10kΩ
Key = A
10kΩ
R4
55 %
R2
1kΩ
Vout
V-
U1A
Vin
R1
1kΩ
U1B
LF353N
V+
LF353N

Audio PCB


2.20
2.65
R7 80k
C7 10n
C6 10n
C5 10n
C4 10n
R14 1k
R13 1k
R12 50k
R6 100k
R5 100k
C3 100n
C2 100n
C1 100n
R10 7.95k
R8 7.95k
R4 26.52k
R3 26.52k
R11 63.662k
R9 63.662k
R2 265.52k
R1 265.52k
JP3
JP1
Designator9
Designator102
<Name>
Designator

3 Digital System

Microcontroller

Requirements:

- Low Power Consumption
- DSP and onboard DAC
- Many communication ports
- Easy development: Launchpad and IDE

MSP 432 overview

MSP432 chip
100-pin flat pack design
1.2x1.2mm
3.3v
ARM
DSP

MSP432 Launchpad
Built-in debugging
Built-in programming
Jumpers to detach dev features

Launchpad

- USB debugging and programming
- Onboard power regulation (3.3v and 5v)
- Pinouts or headers for all pins
- Removable debug jumpers
- MSRP $13

Chip Features:

Ports
SPI
UART
I2C
Serial/GPIO
JTAG/SWD (debugging)

48 MHz Onboard Clock
Internally adjusted
OR
External resistor/capacitor
OR
External power source

DSP
MSP432 DSP libraries
Built-in DSP asm instructions
FFT (512 samples)

ARM Instruction Set
32-bit ARM Cortex-M4F
Contains FPU and memory protection

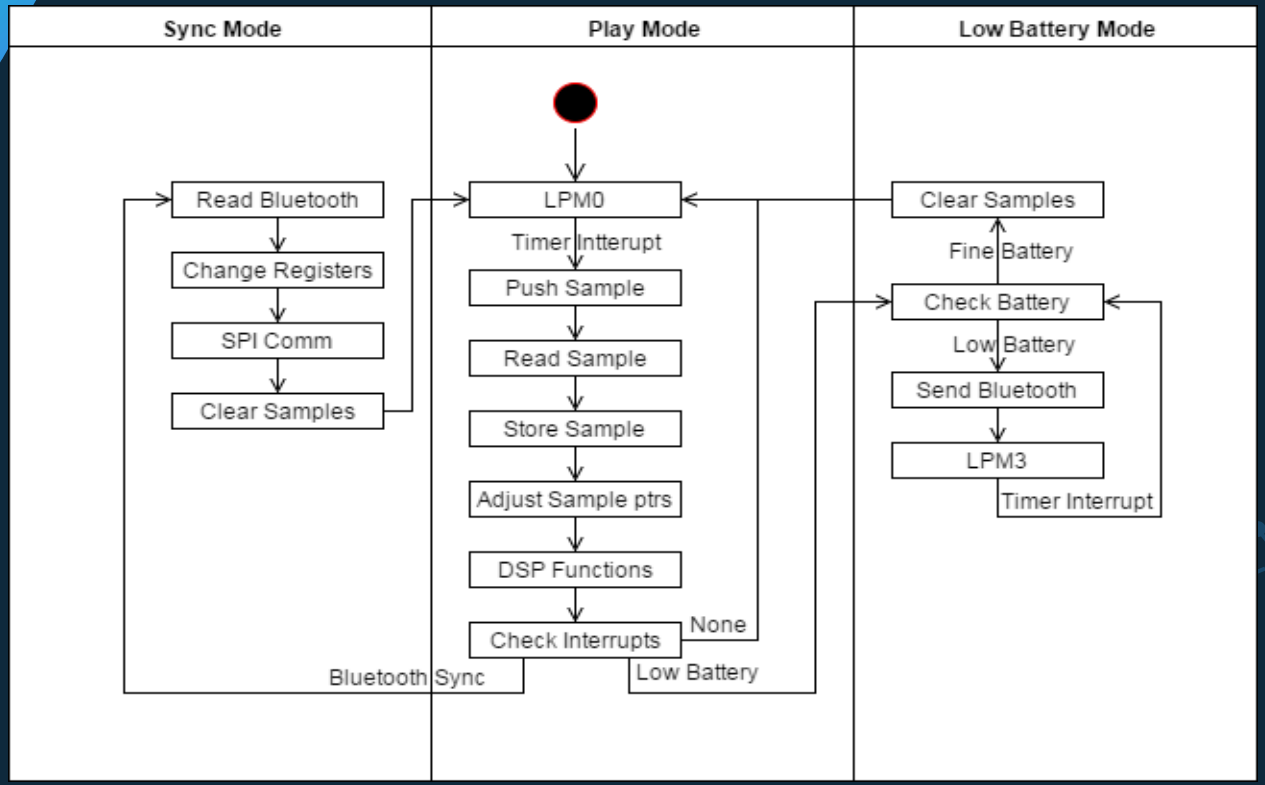
ADC
14-bits (full resolution)
1 MSPS max
Successive Approximation (SAR)

DSP Overview

- Delay base effects in time domain
- Delay, Flanger, Reverb, Chorus, Echo
- Samples will be stored in cyclical array
- Previous samples will be mixed with current sample

After DSP, sample is passed to DAC and MCU goes to sleep.

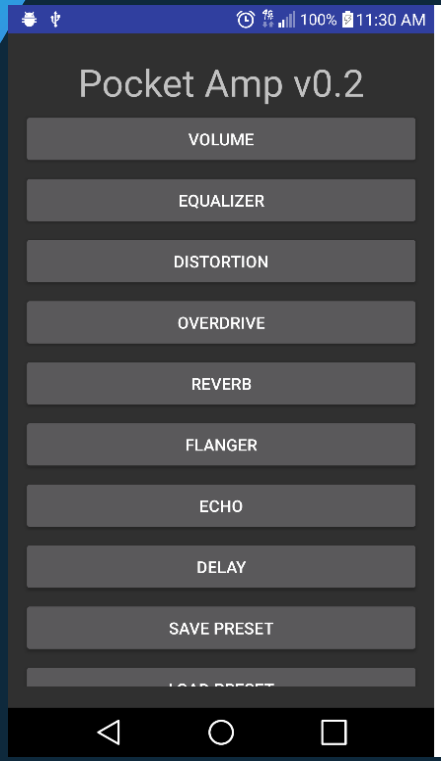
MCU Code

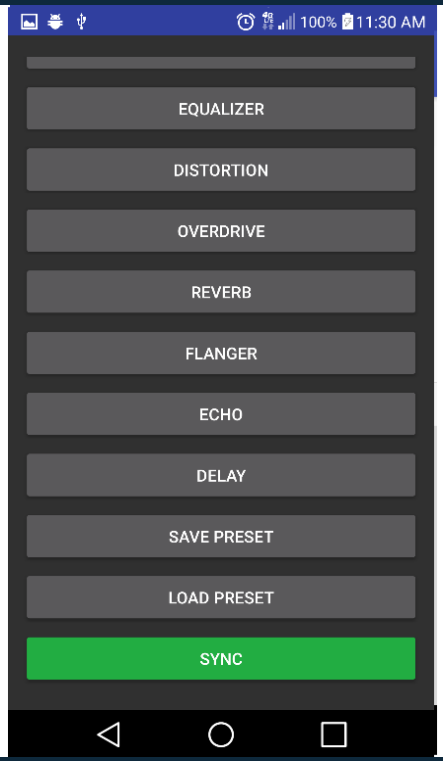

Sync Mode
Play Mode
Low Battery Mode
Read Bluetooth
Change Registers
SPI Comm
Clear Samples
LPM0
Timer Intterupt
Push Sample
Read Sample
Store Sample
Adjust Sample ptrs
DSP Functions
Check Interrupts
None
Low Battery
Bluetooth Sync
Clear Samples
Fine Battery
Check Battery
Low Battery
Send Bluetooth
LPM3
Timer Interrupt

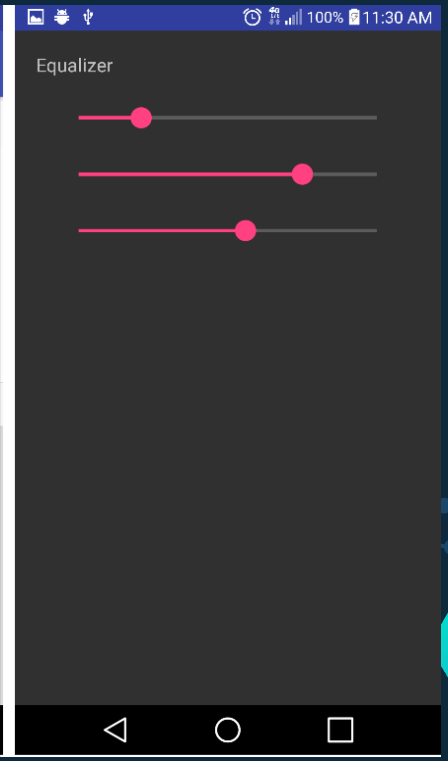
App Overview

- Change settings for all effects
- Save/Load presets
- Sync with Pocket Amp

App (Previous Version)







4 Communication

Interchip Communication

SPI

- 1 Master & 1+ Slaves
- Min 4 wires
- Extra wire for each slave
- Unidirectional wires

I2C

- 1+ Master & 1+ Slaves
- Only 2 wires
- Unique address per slave
- Bidirectional wires

Interchip Communication

MSP432
- I2C
- SPI

I2C
- DAC
- Bluetooth
- Power Supply

SPI
- Potentiometers

App Communication

Bluetooth Classic

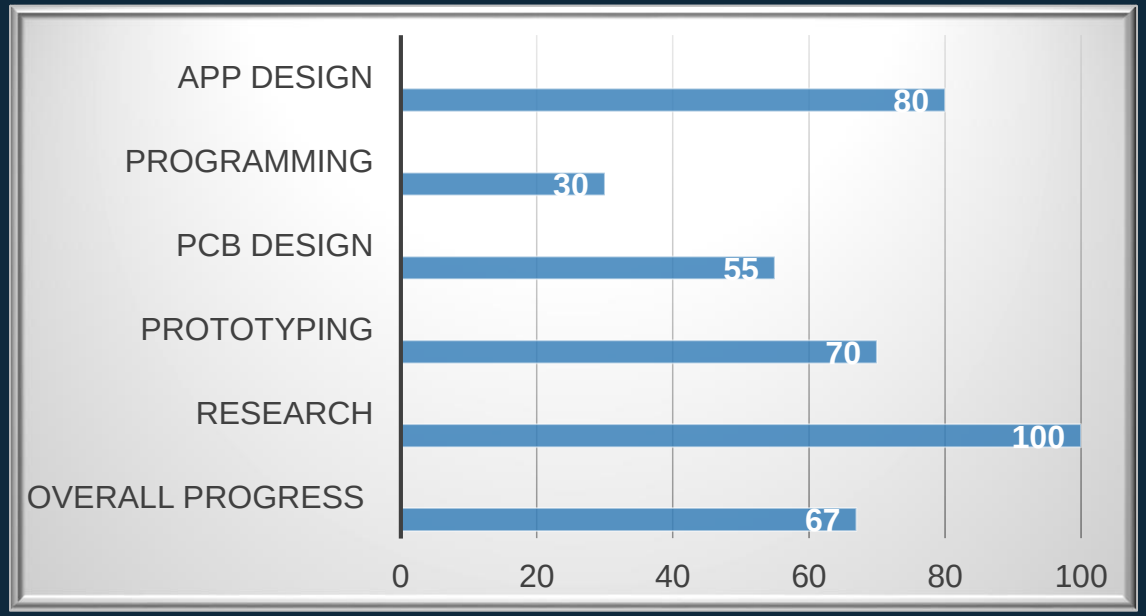
- Pair and maintain connection
- Require its own MCU

Bluetooth Low Energy

- **Only connected when needs to transmit data**

5 Administration

Progress Chart



Primary & Secondary Roles

Subsystem	Primary	Secondary
Analog Signals	Joshua	Trent
Digital Signals	Marissa	William
Power	Trent	Joshua
Software	William	Marissa