The Grainger College of Engineering

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Team 37: M.E.L.O.D.I.C

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Problem/Solution

Question

Is there a chart for the UHF-R that shows how the Group and Channel correspond to a particular frequency?

Answer

G1 = 470 to 530 MHz; U.S. TV channels 14 thrugh 23
H4 = 518 to 578 MHz; U.S. TV channels 22 through 31
J5 = 578 to 638 MHz; U.S. TV channels 32 through 41 (Illegal in the U.S. after June 2020)
L3 = 638 to 698 MHz; U.S. TV channels 42 through 51 (Illegal in the U.S. after June 2020)
X1 = 944 to 952 MHz; U.S. studio transmitter links. (Special order only. Sales manager approval needed).

Question

Why do I hear about TV channels when discussing frequencies for wireless mics?

Answer

Many professional wireless microphones use the same frequencies as broadcast television stations.

Direct conflict with a TV signal causes short range or dropouts. Though it is not possible for an wireless mic receiver to "hear" anything from a digital TV transmission, the DTV signal acts as a very strong broadband radio noise source. In some systems this may result in increased noise or distortion in the audio output.

Commonly Asked Questions on Shure Wireless Audio Forums.

Common issues with wireless audio systems.

Many UHF wireless audio systems operate within the T-Band spectrum, which suffers interference from terrestrial television. These systems must switch channels manually or automatically to avoid interference within the 470-700 MHz range. Many UHF systems are also too costly for amateur musicians.

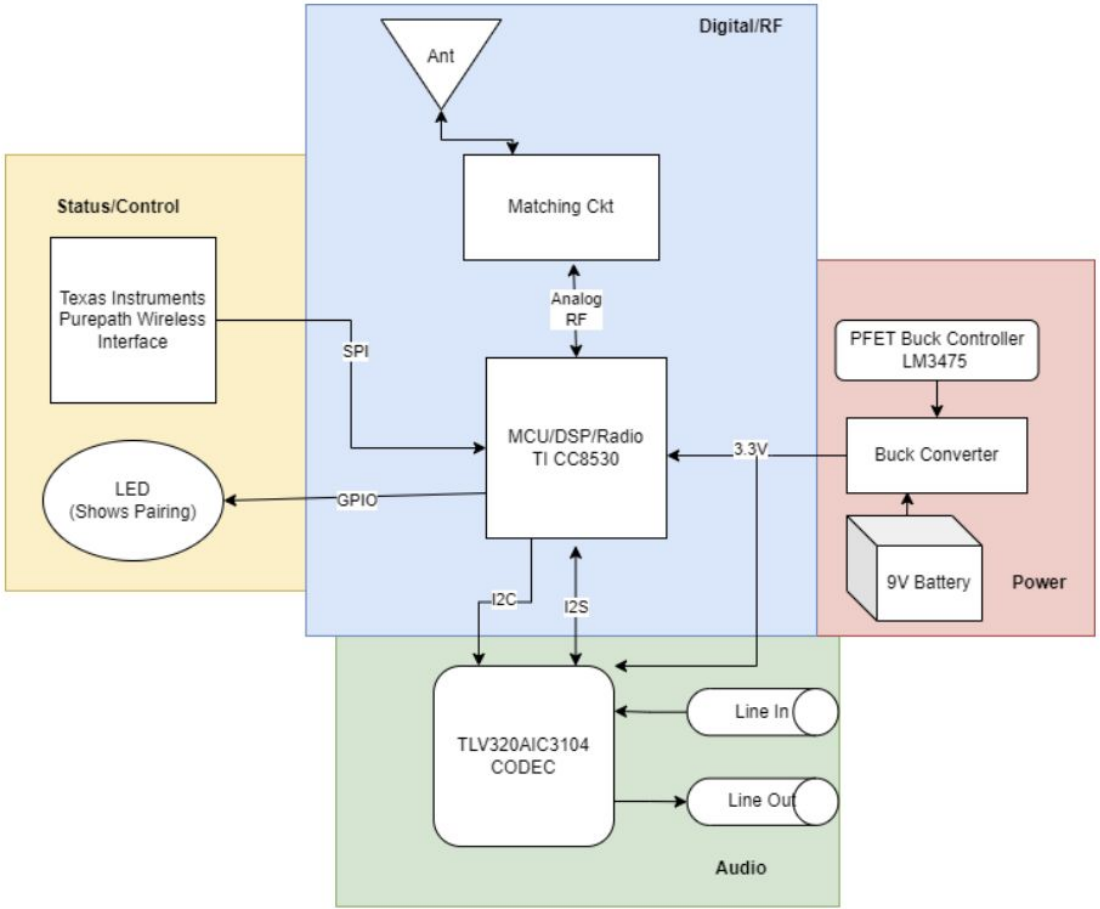
How can MELODIC solve these issues?

Offer an open-source ISM digital wireless audio streaming link.

- **Adaptive frequency hopping for ISM coexistence.**
- **Configurable Differential Mono/Single-Ended Stereo Line-In and Line Out.**
- **Operation in ISM band for FCC unlicensed use.**
- **<$30 to manufacture a single unit.**

Why MELODIC?

Musician's **E**ssential **L**ink for **O**ptimized **D**igital **I**nstrument **C**onnection


Digital/RF
Ant
Matching Ckt
Analog
RF
Status/Control
Texas Instruments
Purepath Wireless
Interface
SPI
MCU/DSP/Radio
TI CC8530
PFET Buck Controller
LM3475
Buck Converter
3.3V
LED
(Shows Pairing)
GPIO
9V Battery
Power
I2C
I2S
TLV320AIC3104
CODEC
Line In
Line Out
Audio

High Level Requirements

CD Quality Audio

- 44.1kHz sampling rate
- Bit depth of 16

Coexist with other 2.4GHz wireless protocols

- Co-existence with other ISM protocols such as WiFi and Bluetooth.
- PER < 1%
- Transmission of 44.1 KHz sampling rate.

Straightforward GUI

- LCD
- Display battery, network stats, device identification

RF and Audio Subsystem

RF Design Requirements

1. AFH successfully negates the effects of frequency dependent interference.
2. RF Power Output Configurable to +10dBM

Audio Design Requirements

1. End-to-End latency must not exceed 20 ms.
2. Input and Output impedance must be 10 KOhm and 600 Ohm respectively.
3. Codec must use sampling rate of 48 KHz at 16 bit depth.

Wireless Audio Sub-Systems Design Considerations

RF Considerations

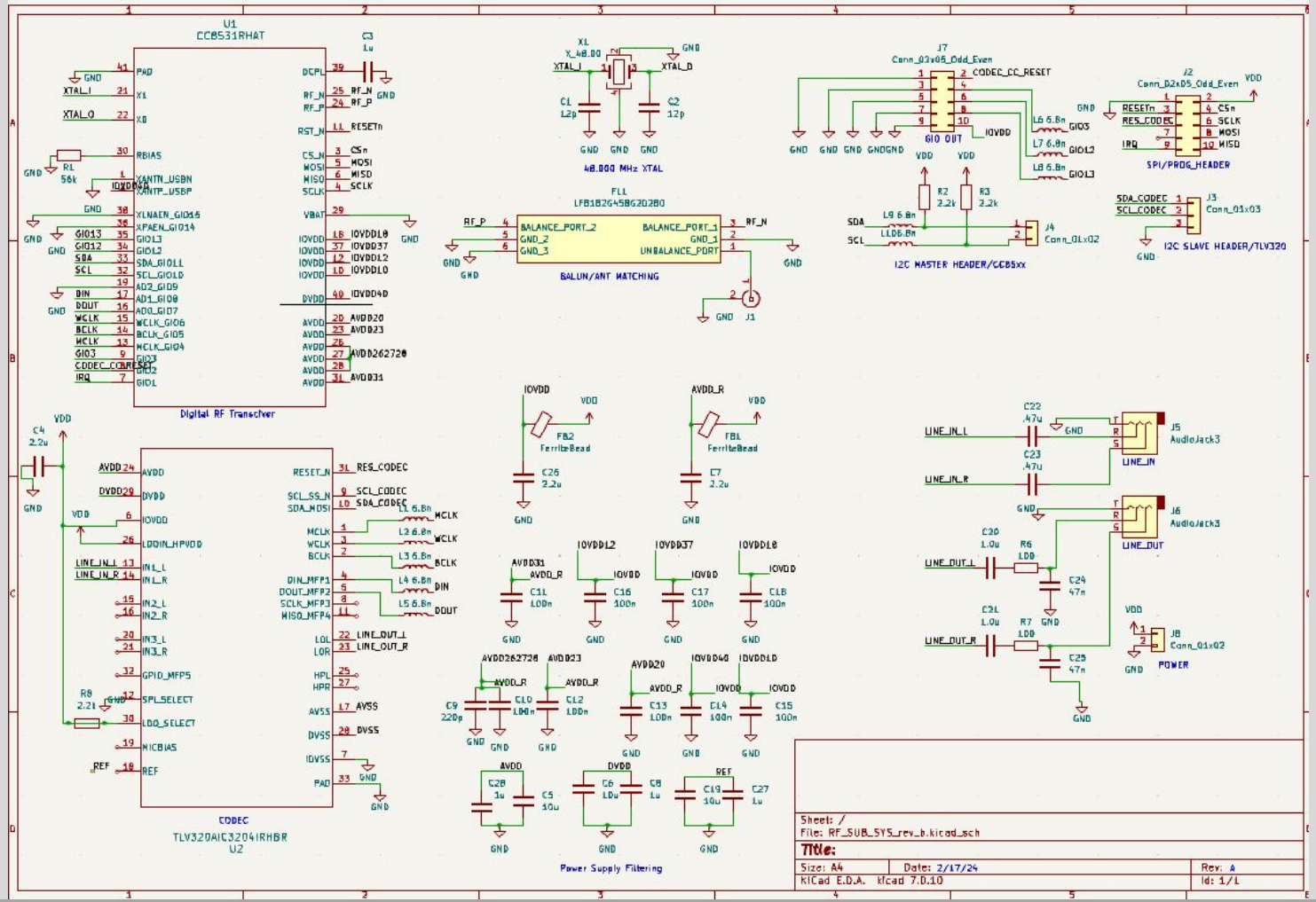
- Characteristic Impedance of Differential Traces ~70 Ohms
- Characteristic Impedance of Single Ended Lines must be ~ 50 Ohms
- RF must be isolated from digital and analog signaling.
- Crystal must have proper load capacitance for frequency stability.

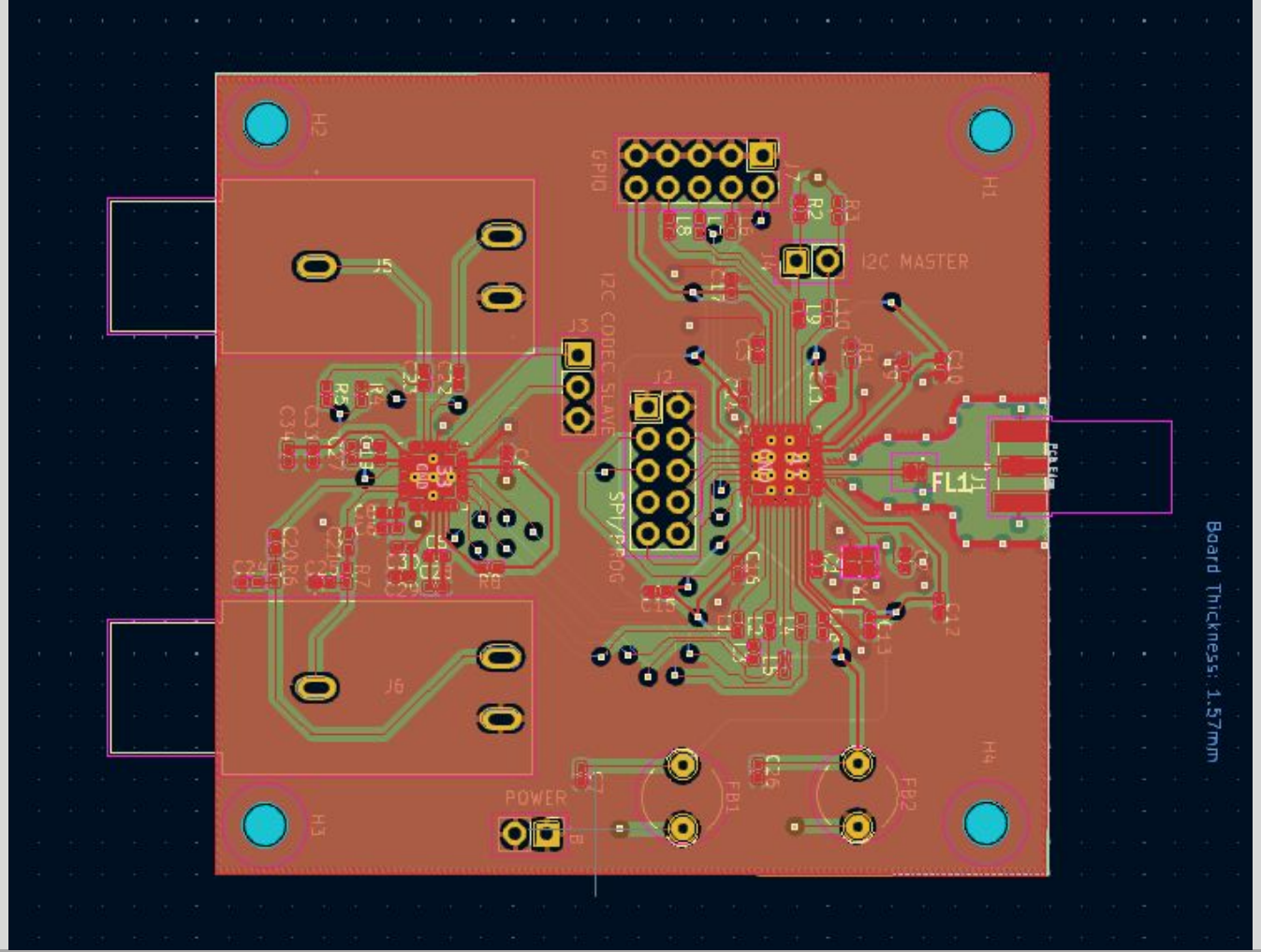
Power Considerations

- All power supplies need decoupling capacitors.
- Analog and digital supplies for transceiver/MCU needed to be filtered with ferrite beads to negate high frequency EMI.
- Codec registers need to be programmed to use internal buck to convert 3.3V IO voltage to 1.8V digital and analog voltages.

Audio Considerations

- Line-In needed a .47uf capacitor for proper charging/discharging time constant for ADC.
- Codec registers needed to be programmed for 10k Ohm input impedance typical for audio.
- Codec registers needed to be programmed for HPF with DC cutoff.


U1
CC8531RHAT
Digital RF Transceiver
XL
X_48.000
48.000 MHz XTAL
FLL
LFB182G45BG2D280
BALUN/ANT MATCHING
J7
Conn_02x05_Odd_Even
GIO OUT
J2
Conn_02x05_Odd_Even
SPI/PROG_HEADER
I2C MASTER HEADER/CC85xx
J3
Conn_01x03
I2C SLAVE HEADER/TLV320
CODEC
TLV320AIC3204IRHBR
U2
J5
AudioJack3
LINE_IN
J6
AudioJack3
LINE_OUT
J8
Conn_01x02
POWER
Power Supply Filtering
Sheet: /
File: RF_SUB_SYS_rev_b.kicad_sch
Title:
Size: A4
Date: 2/17/24
Rev: A
KiCad E.D.A. kicad 7.0.10
Id: 1/1


GPIO
I2C MASTER
I2C CODEC SLAVE
SPI/PROG
POWER
FL1
J6
H1
H2
H3
H4
FB1
FB2
Board Thickness: 1.57mm

Audio Codec Programming

Initialize internal clock dividers and device mode registers. (Protocol Slave and Master)

1. Pull reset pin high to reset device.
2. Enable internal software reset through I2C
3. Set NDAC/ADC divider to 1 and MDAC/ADC divider to 4 for ADC and DAC sampling frequency of 48 KHz. This is based on a 10.2475 MHz device input clock.
4. Program oversampling ratio to 64 as per the datasheet for 48KHz sampling rate.
5. Set DAC to use PRB_P8 mode which allows for 4 biquad filters and dynamic range compression, and uses the interpolation filter B.

Initialize power blocks. (Protocol Slave and Master)

1. Disable AVDD from external supply.
2. Power on the internal AVDD buck/LDO
3. Power on all the analog blocks.

Route and Output DAC for Single-Ended Stereo Line-In (Protocol Slave)

1. Route the left and right DAC to the line-out left and right ports.
2. Unmute the line-out drivers with 0dB of gain.
3. Set DAC digital volume output to 0dB.
4. Power up line out drivers
5. Power up the left and right DAC
6. Unmute the left and right DAC.

Route and Input ADC for Single-Ended Stereo Line-Out (Protocol Master)

1. Route the IN1L input to the positive terminal of ADC with 10 K-ohm input
2. Route the CM1L common mode output to negative terminal of ADC with 10 K-ohm input.
3. Repeat above for the IN1R port.
4. Unmute the left and right programmable gain amplifiers.
5. Power up the left and right ADC.
6. Unmute the left and right ADC.

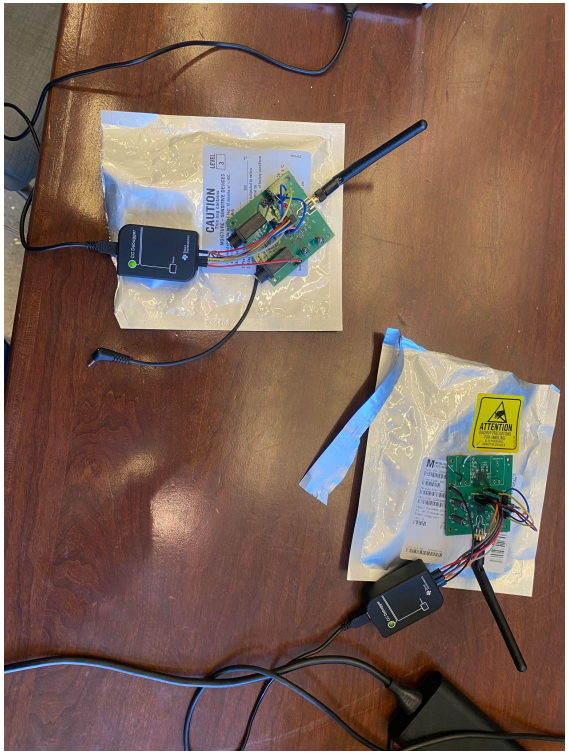
Audio Codec Programming (Continued)

Initialize Digital Filter Constants for Line-In DC filter. (Protocol Master)

```
# DC FILTER LEFT CHANNEL
w 30 00 08    # Select register page 8
w 30 18 7F    #              n0 + n1 * z^-1
w 30 19 FF    #     H(z) = ----------------------
w 30 1A 00    #              2^23 - d1 * z^-1
w 30 1C 80    #
w 30 1D 01    # The constants are defined as
w 30 1E 00    #     n0 = 32767 * 256
w 30 20 7F    #     n1 = -32767 * 256
w 30 21 FC    #     d1 = 32768 * 256 * (1- 2^13)
w 30 22 00    # This gives a filter with cutoff at approx. 1 Hz
# DC FILTER RIGHT CHANNEL
w 30 00 09    # Select register page 9
w 30 20 7F    #              n0 + n1 * z^-1
w 30 21 FF    #     H(z) = ----------------------
w 30 22 00    #              2^23 - d1 * z^-1
w 30 24 80    #
w 30 25 01    # The constants are defined as
w 30 26 00    #     n0 = 32767 * 256
w 30 28 7F    #     n1 = -32767 * 256
w 30 29 FC    #     d1 = 32768 * 256 * (1- 2^13)
w 30 2A 00    # This gives a filter with cutoff at approx. 1 Hz
```

Wireless Audio Testing and Verification

Wireless Test Setup



Two MELODICs in an ISM coexistence environment

Decoded data

Index	Name	Value
[0:3]	N_TIMESLOTS	136229 (0x00021425)
[4:7]	N_RX_PKT	6012 (0x0000177C)
[8:11]	N_RX_PKT_FAIL	4814 (0x000012CE)

Protocol slave PS_RF_STATS register values after a couples seconds of audio streaming

[0]	PEAK_VALUE	18 (0x0012)	Maximum absolute peak value observed
[0]	MEAN_VALUE	0	Mean absolute value (filtered)
[1]	PEAK_VALUE	32767 (0x7FFF)	Maximum absolute peak value observed
[1]	MEAN_VALUE	23233 (0x5AC1)	Mean absolute value (filtered)

Protocol slave PS_RF_STATS register value with protocol master transmitting audio

Ultimately, samples are transmitted but PER causes them to be muted. If PER was <1% then samples would have outputted unmuted.

Why such a high PER?

Inexperience in RF design simulation.

To find the proper differential trace lengths, I used the PCBWay online calculator.

To verify, I used Keysight ADS S-Parameter simulation of edge-coupled transmission line with thickness of Inner Cu. and Front Cu. height.

Simulation did not take into account certain geometries of the actual tracks or it's length, nor take into account other layers on the board. Measurement plane was only done between CC8530 to balun and balun to SMA port.

How this could have been mitigated.

The PCBWay calculator is only an approximation of the true equations.

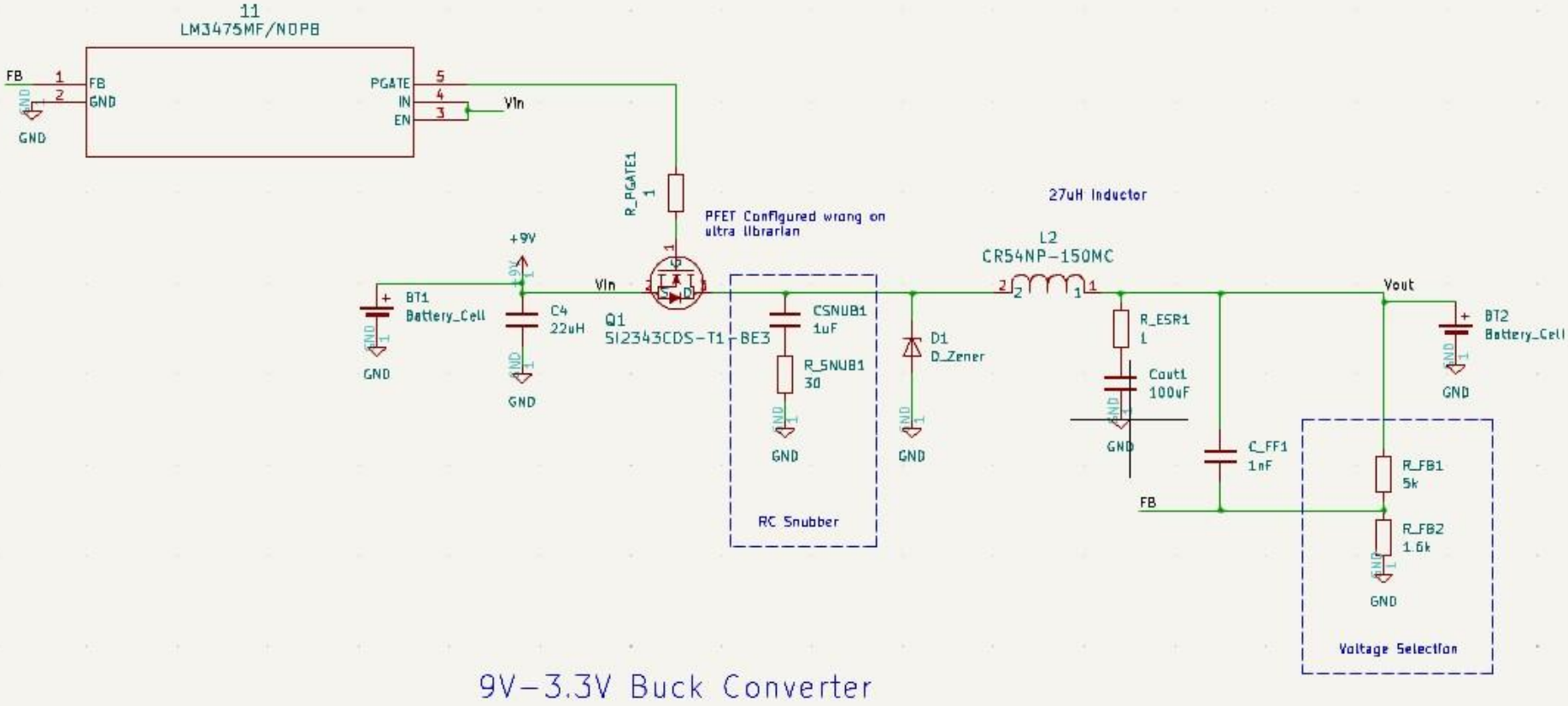
The ADS S-Parameter Simulation should have been a 1:1 match geometrically with the board layout.

Board simulation should have taken into account the different layers, not just Front Cu., Mid. Prepreg, and Inner Cu.

S-Parameter simulation should have taken into account geometric discontinuities between ports and should have modeled entire RF front end.

Power Subsystem

Power Subsystem

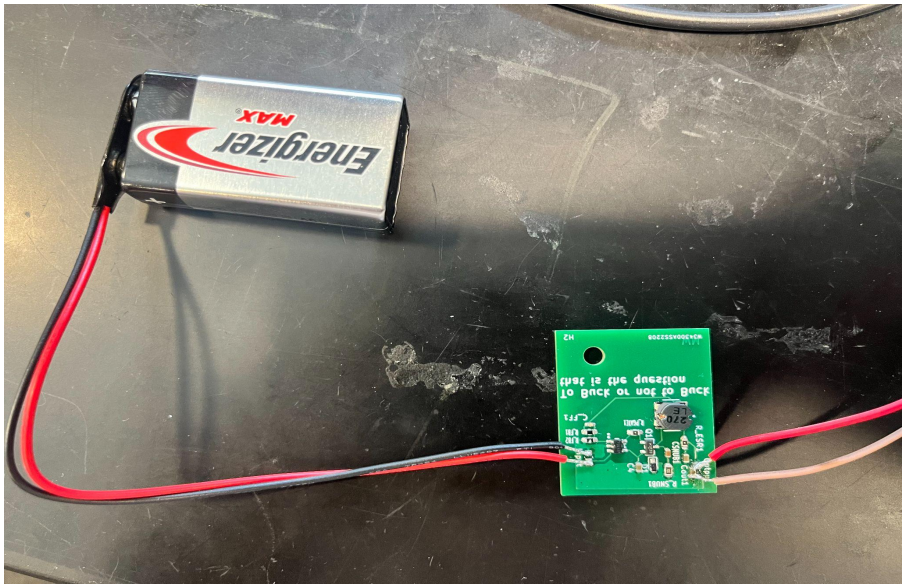


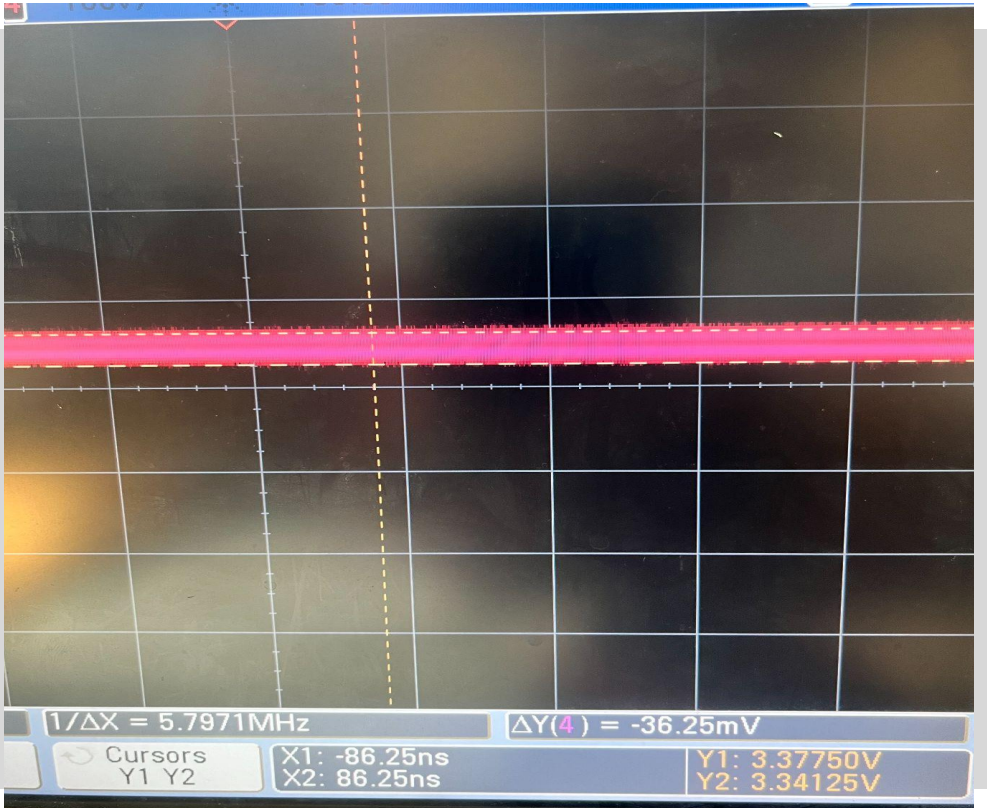
9V–3.3V Buck Converter

Power Design Requirements

1. The buck converter must provide stable 3.3V from the 9V battery
2. Average noise on 3.3V line must be less than 50 mV p-p
3. Power conversion efficiency must be at least 85% under full load.
4. The battery must be able to last a minimum of 5 hours with adequate charge.

1. **The buck converter must provide stable 3.3V from the 9V battery**



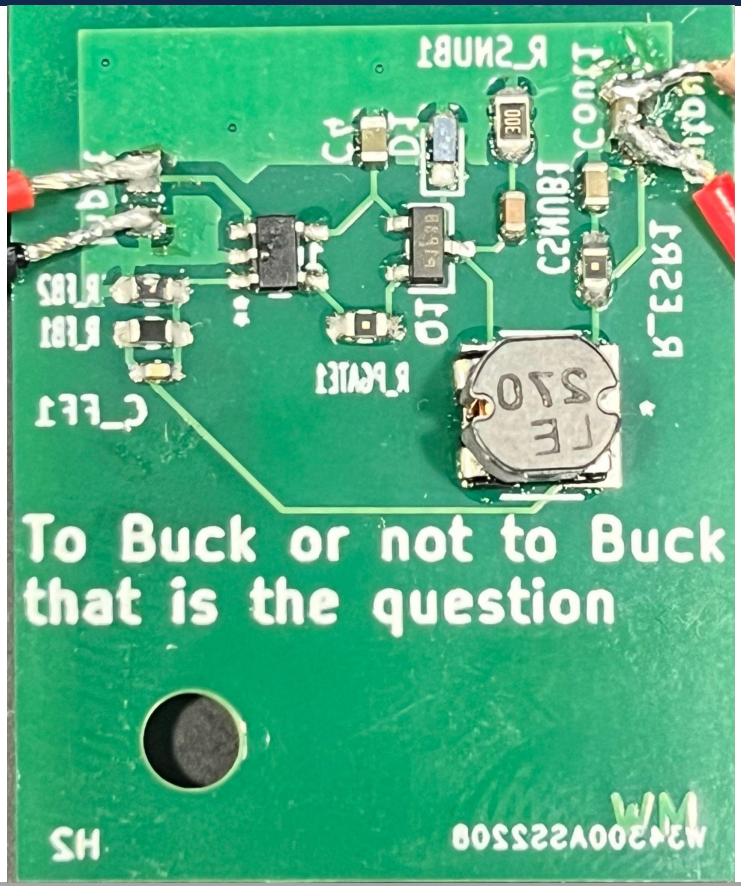


2. Average noise on 3.3V line must be less than 50 mV p-p

- Average noise is 37mV p-p
- Only hysteretic ripple is present
- Achieved

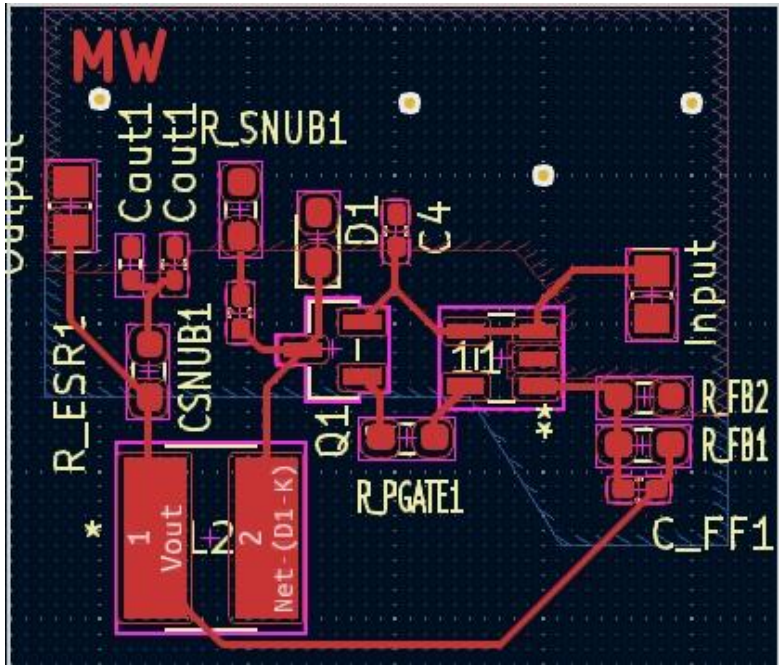
3. Power conversion efficiency must be at least 85% under full load

- Efficiency varies under differing loads
- 60mA max load
- Attached a 55Ω resistor and read input values
- Achieved a maximum efficiency of 82.5%



4. The battery must be able to last a minimum of 5 hours with adequate charge

- 60mA max output current
- Assuming average efficiency of 80%
- 27.5mA draw at 9V
- Average 9V 550mAh
- **20hr battery life**



Setbacks:

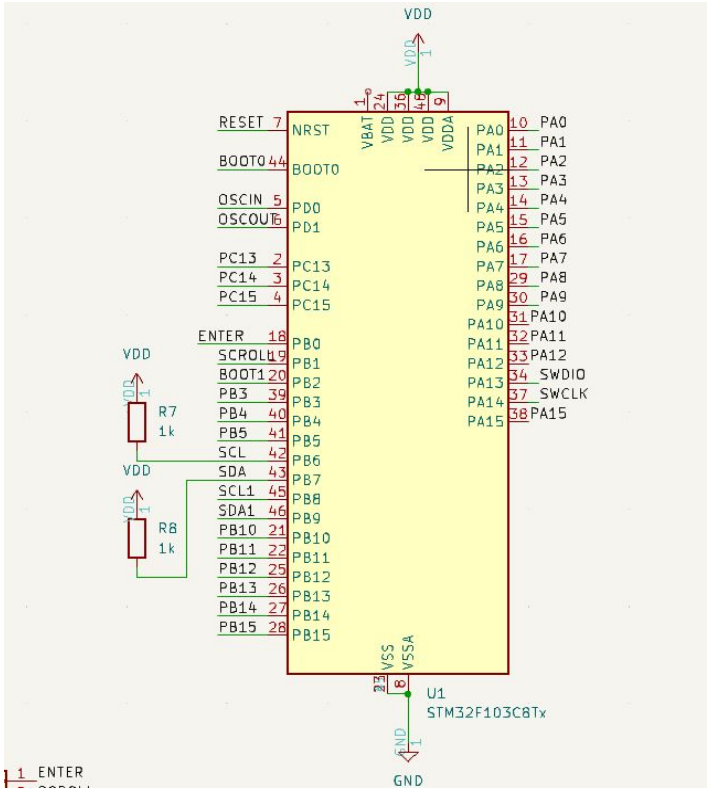
- Incorrect parts orders
- Missing PCB order
- Insufficient design values
  - Csnub value increased to 4.4uF

Solutions:

- Doubled up components on pads
- Used larger parts

.

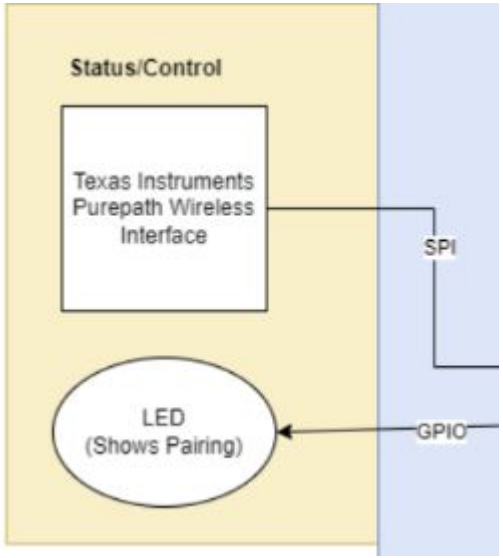
Control Subsystem



STM32F103C8T6 MCU Pinout

Original Design

- STM32F103C8T6 MCU acts as host interface to program and read stats from ICs
- Programs CC8530 RF IC and TLV320AIC3204 Audio Codec using SPI and I2C buses respectively
- 16x2 LCD displays necessary info



New Control Block Diagram

New Design

- CC8530 and TLV320AIC3204 ICs interfaced using Texas Instruments Purepath Wireless Configurator/Commander
- Devices are Flash-Programmed as Master or Slave
- Flashing LED shows Pairing/Paired Devices once relevant SPI commands are sent

SPI Commands for Pairing in Host-Controlled Mode

- One CC85xx is flash-programmed with Host-Controlled Master Firmware
- NWM_CONTROL_ENABLE is invoked by the master to begin pairing process
- NWM_DO_SCAN is invoked by slave, master device ID is returned
- NWM_DO_JOIN is invoked by slave with master ID as argument
- Use NWM_GET_STATUS on both master and slave to see information about current audio network
- Use PS_AUDIO_STATS and PS_RF_STATS to see RF and Audio statistics (used in verification)

Master Device ID

Decoded data

Network	Name	Value	Description
[0]	DEVICE_ID[31:0]	558283385 (0x2146BA79)	Network ID of current network (device ID of master). A value of 0 means no active network connection
[0]	MANF_ID[31:0]	1	Manufacturer ID of protocol master (0=not connected)
[0]	PROD_ID[31:0]	16 (0x00000010)	Product ID of protocol master (0= not connected)
[0]	-	3	Reserved
[0]	WPM_DSC_EN	1	Indicates that master supports data side channel communication
[0]	WPM_MFCT_FILT	0	Indicates that master only accepts slaves with matching manufacturer ID into network
[0]	WPM_PAIR_SIGNAL	0	Indicates that master is signaling that it is attempting to pair with a new slave
[0]	WPM_ALLOWS_JOIN	1	Indicates that master can accept more slaves into network

Scan Result Becomes Parameter for NWM_DO_JOIN

[0:1][14:0]	JOIN_TO[11:0]	100 (0x0064)	Timeout in increments of 10 ms for joining network. (0=infinite). Using a JOIN_TO value below 50(=500 ms) is not recommended.
	DEVICE_ID[31:0]	558283385 (0x2146BA79)	Network ID of network to join (device ID of master). A value of 0x00000000 means leave network if currently connected. A value of 0xFFFFFFFF means join any network where master is currently attempting to pair with a new slave

NWM_DO_SCAN and NWM_DO_JOIN SPI Operations

Control Subsystem

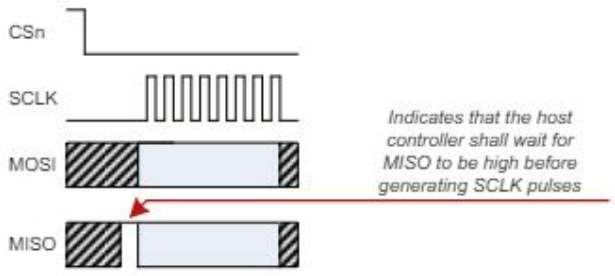


Figure 52 – SPI interface wait state

****MISO Bus read high always before and after CSn pulled low, making reading debugging/statistics bytes impossible*****

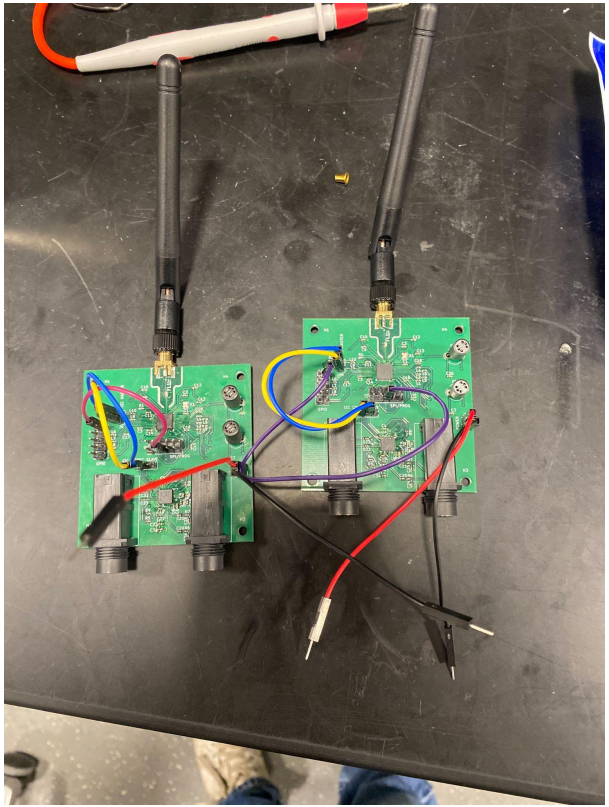
Setbacks:

- Interfacing with STM32 MCU proved difficult
- No Serial Interface on ST-Link
- Texas Instruments' Proprietary SPI Interface Difficult to Work with
- LCD Debugging nearly impossible without precise timing
- Final control unit PCB didn't work (soldering issues)

Solutions:

- Used Texas Instruments Purepath Wireless Configurator/Commander as Control Unit
- Time permitted, we could have used a TI MSP430 MCU, designed to interface with TI ICs, to solve SPI timing issues
- Retry soldering STM32 board (given more time)

Future of MELODIC



Improvements:

- Human-friendly user interface and enclosure.
- Inclusion of PA/LNA for the RF signal chain.
- Create one board for all three subsystems.
- Single audio master capable of transmitting to multiple slaves.
- Add another audio port to allow for differential stereo.
- Add both XLR and ¼ inch. TRS. as audio master inputs. (Might require a rack-mountable enclosure)

Questions?

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IMAGE

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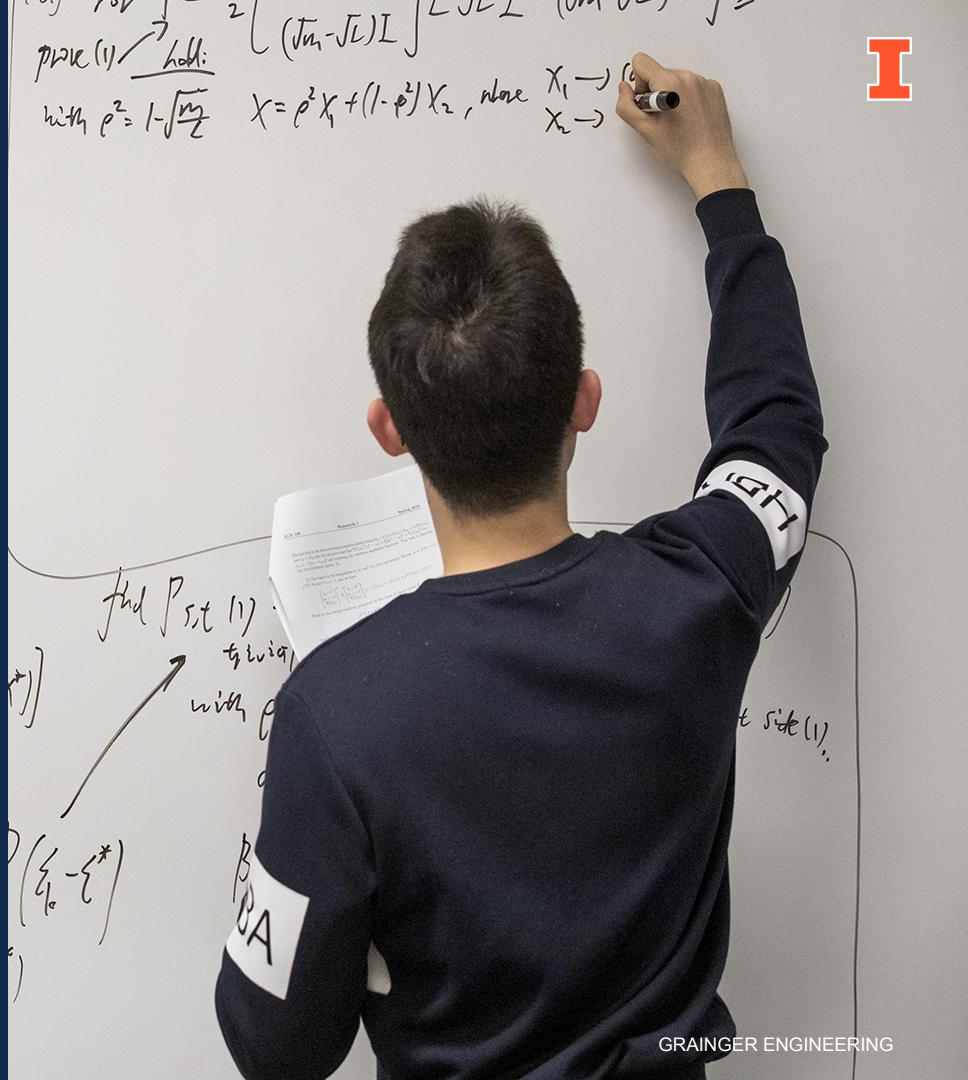

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Summary
Thank You
Questions
Contact Information

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MELODIC Test Setup

IMAGE / GRAPHIC

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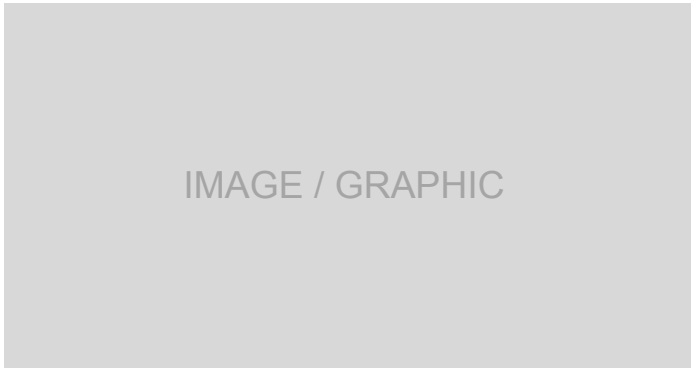

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