

Garmin Power Sensor Test Fixture

GROUP: MAY1729

Client - Jeramie Vens

Advisor – Dr. Degang Chen

Meet the Team

- Brandon Floyd, EE – Team Leader
- Amna Aftab, EE – Key Concept Holder #1
- Xi Zhu, EE – Key Concept Holder #2
- Stephen Julich, CpE – Webmaster
- Francis Wagner, EE – Communication Leader

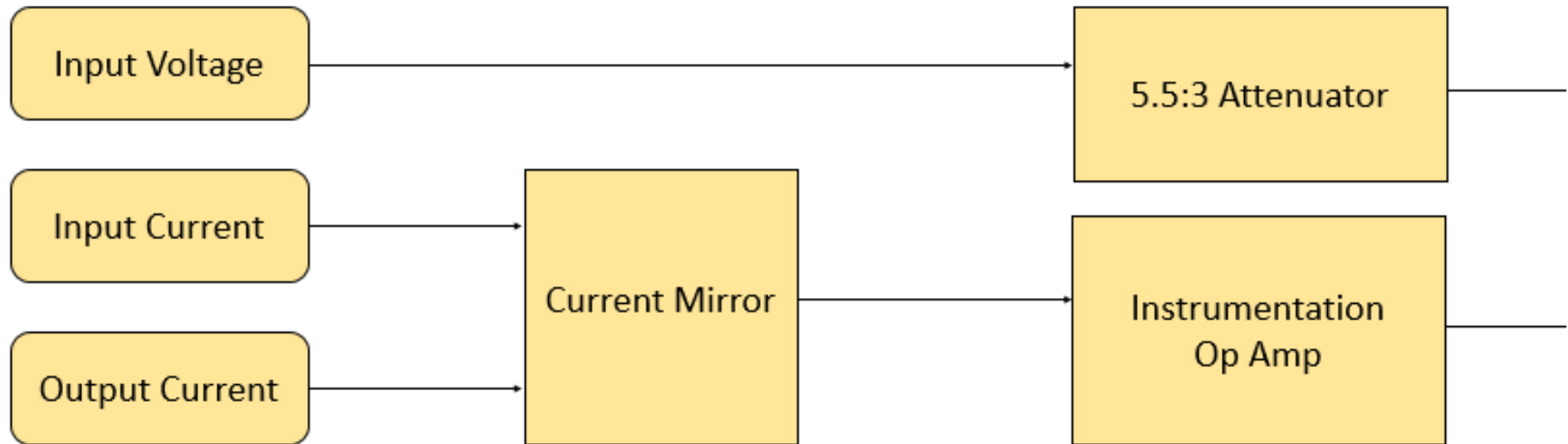
Problem Statement

- Garmin engineers want a tool to measure the power consumed by sections of their fitness electronics circuits.
- Data measurements will be taken overnight and stored on an SD card.
- Both current and voltage must be measured when connected to these electronics. Current must be observed non-destructively.

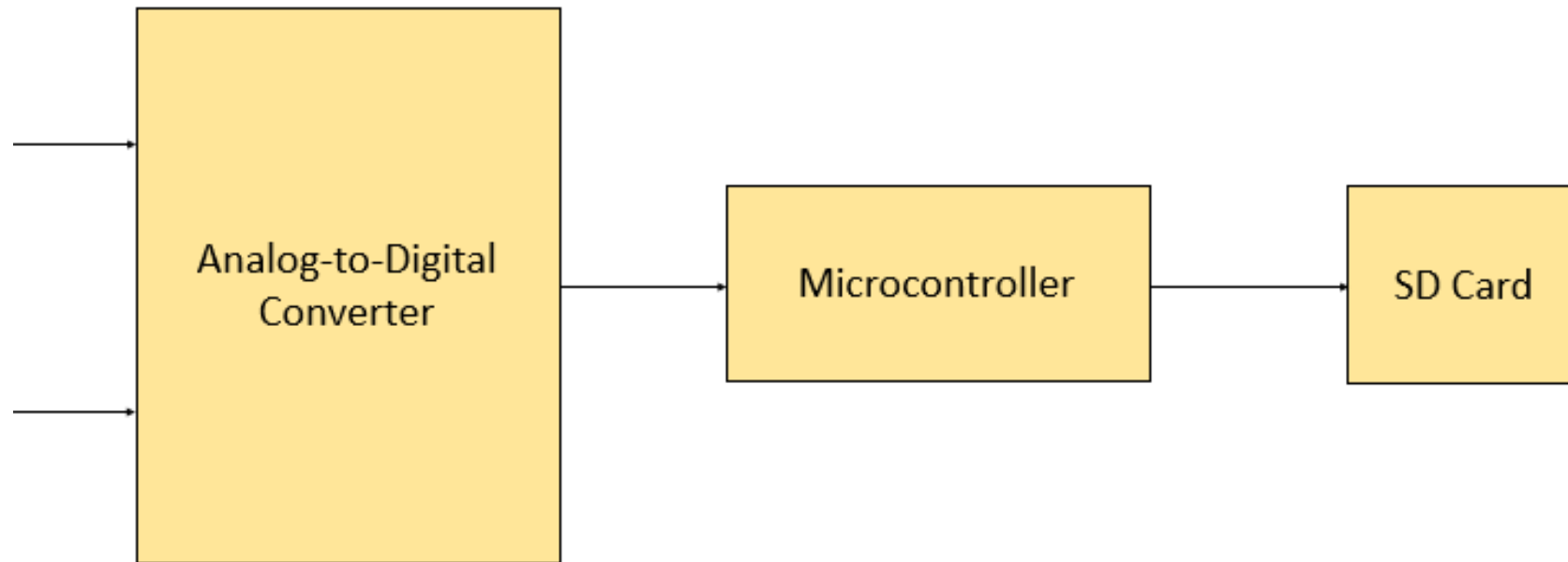
Functional Requirements

- Measure currents from 10 μA to 10 mA
- Measure voltages from 0 to 5.5 V
- Convert voltage range to 0 to 3.0 V for ADC input
- Use microcontroller to compute power consumption with above measurements
- Replicate first channel circuit to bring channel total to 8
- Use SD card to store large amounts of data

Design Overview



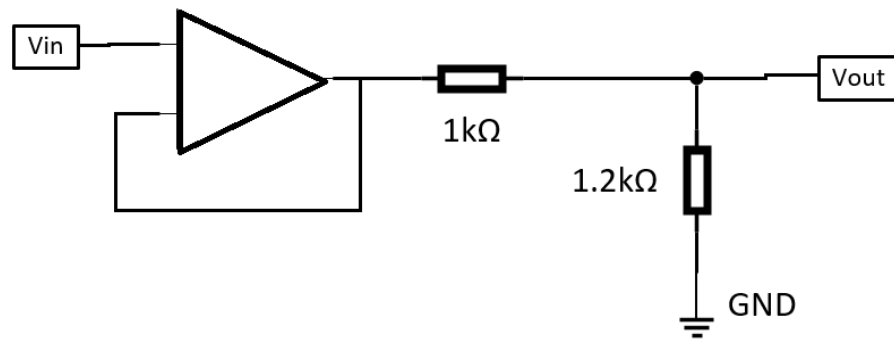
Design Overview Continued



Voltage Measurement

- Source voltage range from 0-5.5V
- Attenuate voltage to 0-3V for ADC using simple voltage divider
- Linear Relationship
- Voltage buffer to isolate attenuator

Circuit Design: Attenuator

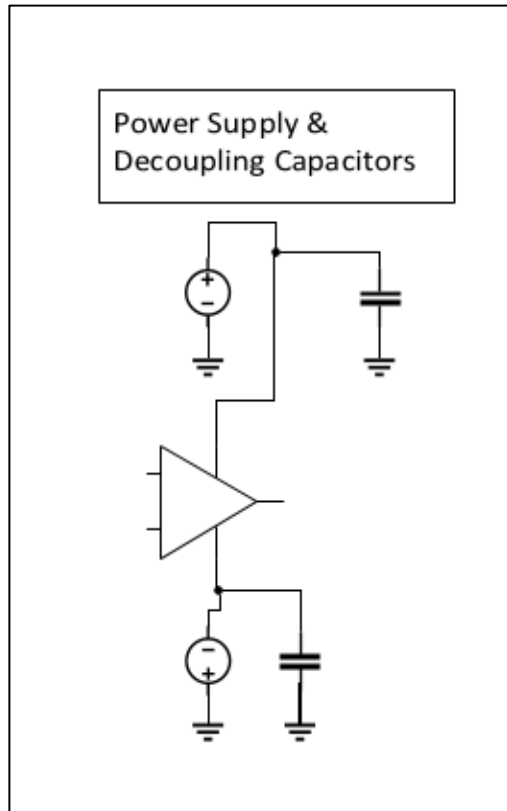


$$V_{out} = V_{in} \cdot \frac{R_1}{R_1 + R_2}$$

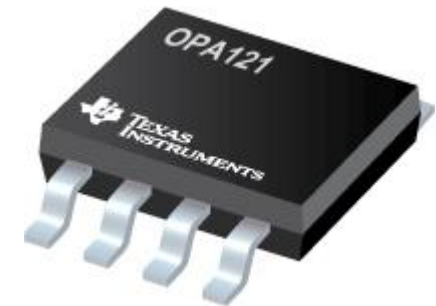
Texas Instruments OPA121

- Used for both the attenuating and current mirror sections of the circuit
- Can handle all ranges of current from 10 μA to 10 mA
- Typical input offset voltage of +/- 0.5V
- Typical input offset current of +/- 0.7pA
- Common mode input range of +/- 11V
- Open loop voltage gain of 114 dB

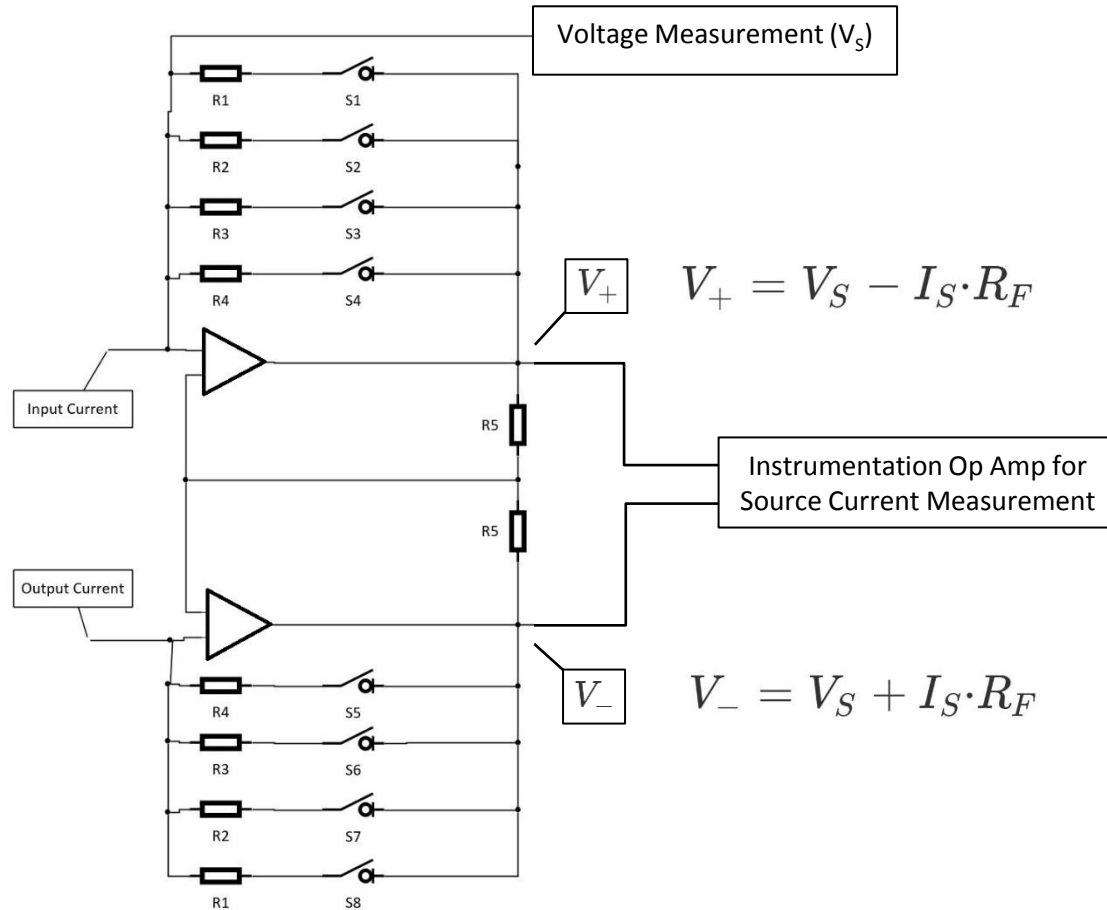
Texas Instruments OPA121 Continued



- +/- 10V Supply
- Decoupling capacitors are needed here to protect the supply input voltage of the op amp
- This op amp works with all the current ranges needed.
- This was selected from general purpose Op amps with low noise.



Circuit Design: Current Mirror



Example: Source is 5V, 1mA.

$$R_F = 200\Omega$$

$$V_+ = 5 + (1 \cdot 10^{-3}) \cdot 200 = 5.2V$$

$$V_- = 5 - (1 \cdot 10^{-3}) \cdot 200 = 4.8V$$

These measurements would be used to select our instrumentation op amp (INA).

Current Mirror Settings

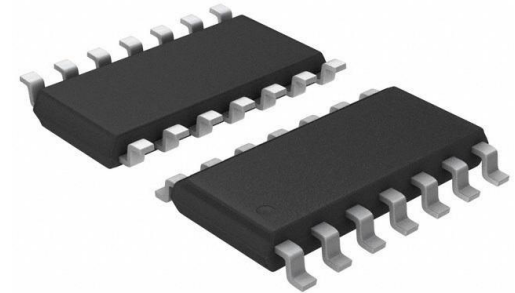
Range Min	Range Max	Switches ON	Feedback Resistance	Precision
0 A	10 μ A	S1/S8	20k Ω (R1)	+/- 0.01 μ A
0 A	100 μ A	S2/S7	2k Ω (R2)	+/- 0.1 μ A
0 A	1mA	S3/S6	200 Ω (R3)	+/- 1 μ A
0 A	10mA	S4/S5	20 Ω (R4)	+/- 10 μ A

Example: Input current = 0.5 mA

- Choose the 1mA range (200 Ω feedback resistor)
- To do so, close switches S3 & S6 (leave the rest open)
- The accuracy of the measurements will be within 1 μ A

Texas Instruments INA163

- Used for current measurement off of current mirror circuit
- Low noise, low distortion
- Gain can reach 100 V/V if necessary
- Accurate and flexible
- Input voltage range that suited our measurements
- +/- 18V Power Supply



Theoretical Results

$$V_+ = V_S - I_S \cdot R_F$$

$$V_- = V_S + I_S \cdot R_F$$

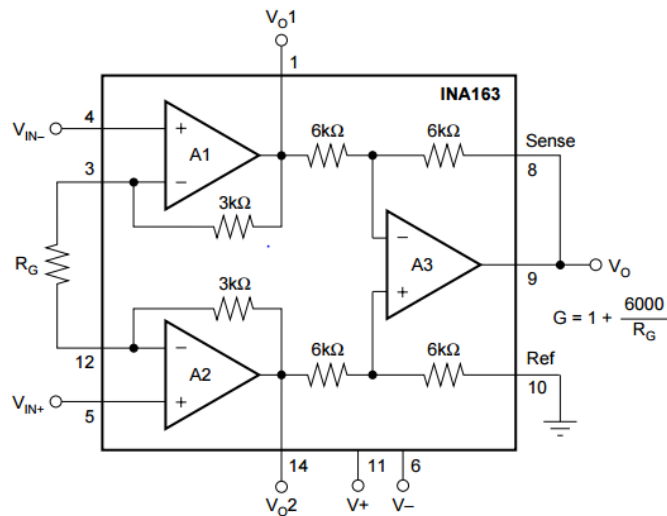
$$V_{cm} = V_+ + V_- = 2V_S$$

$$V_{dm} = V_+ - V_- = 2I_S \cdot R_F$$

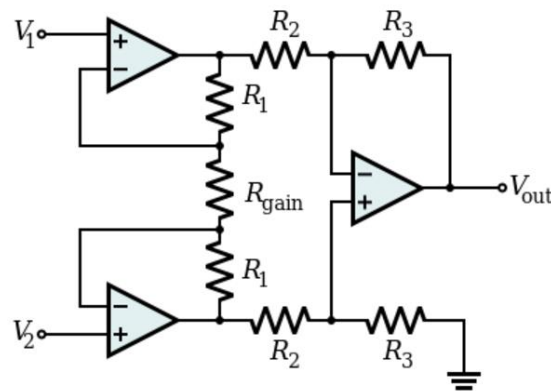
V_+ and V_- are the voltages at the input pins for the INA. Measurements taken here during Multisim simulations were used to determine the common mode and differential mode voltage ranges so we could choose the INA we were going to use.

Using the Differential Mode voltage V_{dm} and our known current range I , we could also calculate which feedback resistor R_F was needed for each current range to be measured.

With our INA's gain G being given in the data sheet, we could select a resistor R_G that would give us the gain we needed to for our circuit.



$$R_g = 931\Omega$$



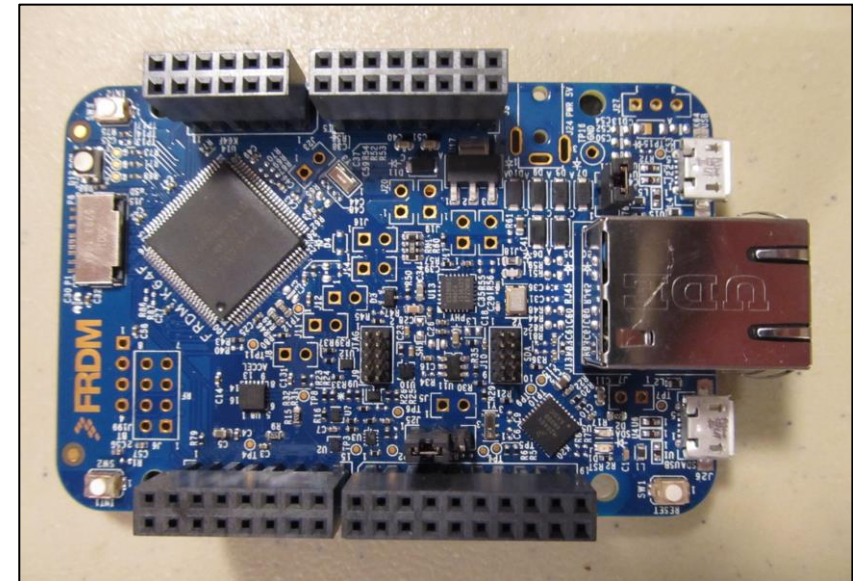
$$\frac{V_{out}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{gain}} \right) \frac{R_3}{R_2}$$

Client Requirements

- Select a microcontroller from the NXP FRDM Line of Development Boards
- Set up 16 ADC inputs to measure circuit voltage and current on 8 channels
- Current should be measured at a minimum rate of 10 ksamples per second
- Voltage should be measured at a rate 1 sample per second
- Unattended Data Logging to an SD card for up to 16 hours

FDRM-K64F Development Board

- 120 MHz ARM Cortex-M4 core
- 1 MB flash memory
- 256 KB RAM
- Two 16-bit SAR ADCs
- Micro SD Card Reader
- USB full-/low-speed On-the-Go controller
- Will plug into the team-designed PCB



ADC Design

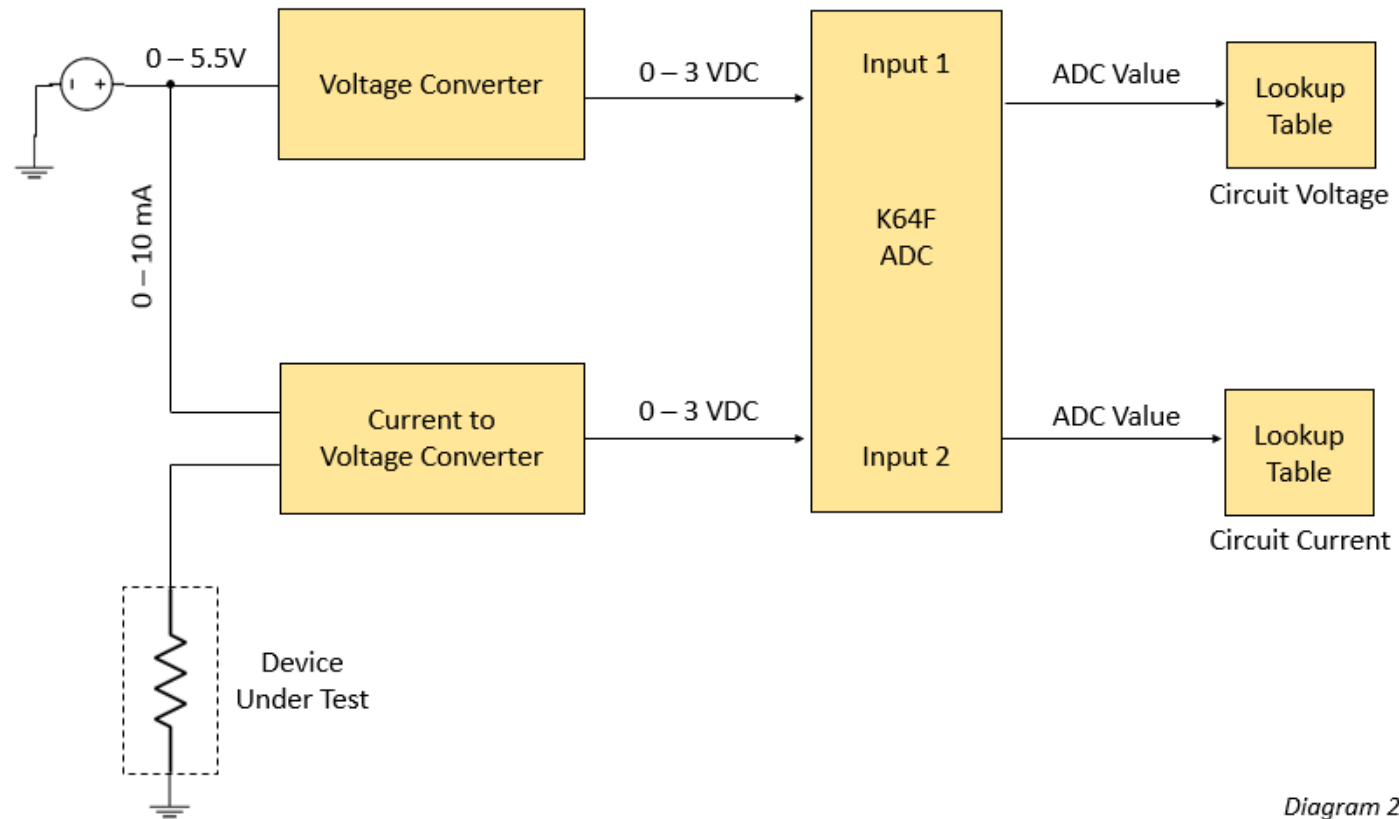


Diagram 2

Firmware/Software Design

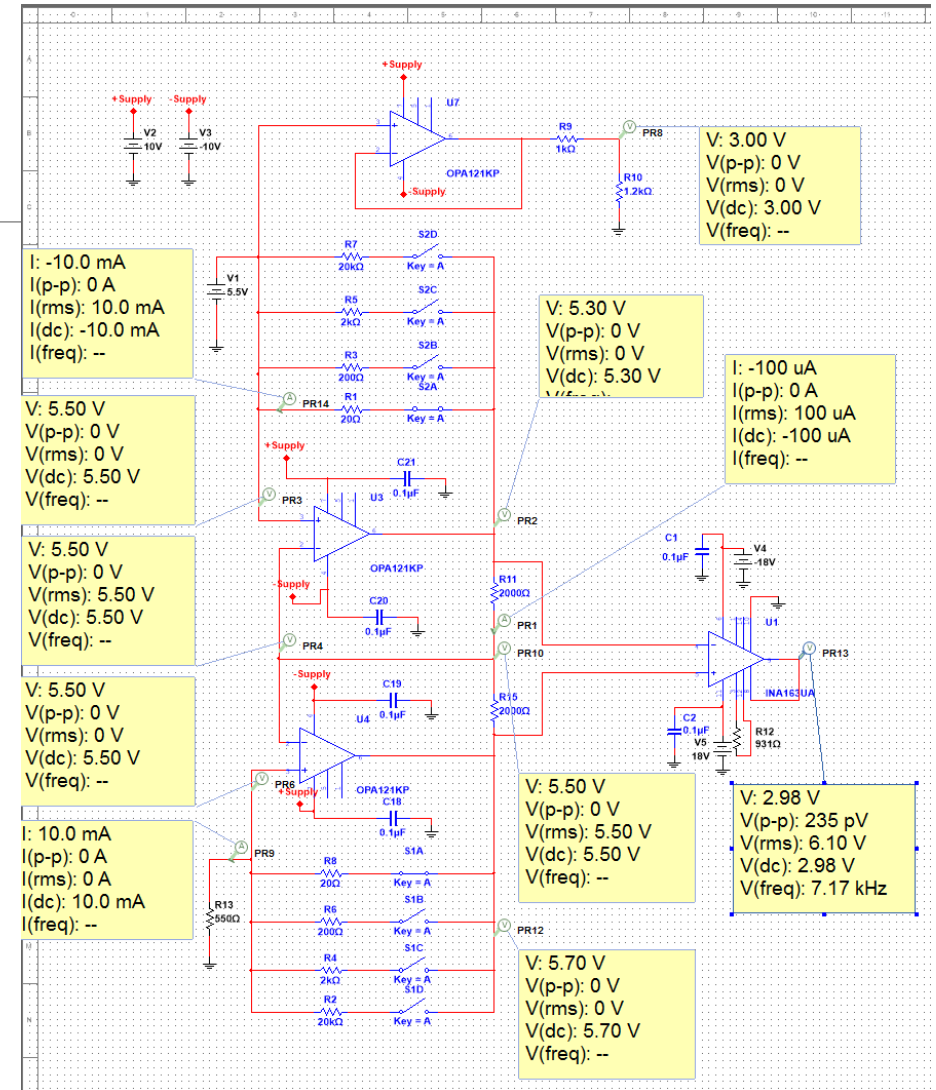
- Select an appropriate FDRM microcontroller board
- Configured and learned software development tools
- Wrote a UI utilizing the debug UART port
- Integrated ADC, DAC, RTC, and SD Card libraries into the project and wrote initialization code
- Wrote code to read 16 ADC inputs
- Wrote code to measure sampling rate using the RTC

PCB Design

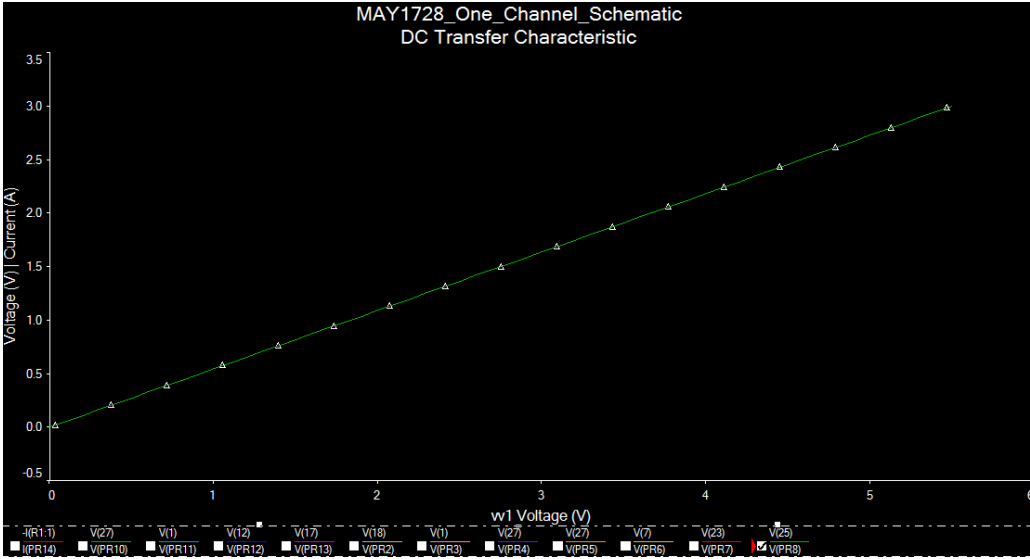
- Concept Diagram and Circuit Design on Microsoft Visio
- Simulations on breadboard, PSPICE, and Multisim
- Original design on CADSTAR
- Switch design to Multisim
- 4.2 inches x 2.2 inches
- ~ 45 Components

Multisim Testing: Current Mirror & Instrumentation

- Current In = Current Out
- Test performed with max input 5.5V
- Current in is max input 10mA
- INA Output < 3V
- 550Ω Resistor to simulate device under testing

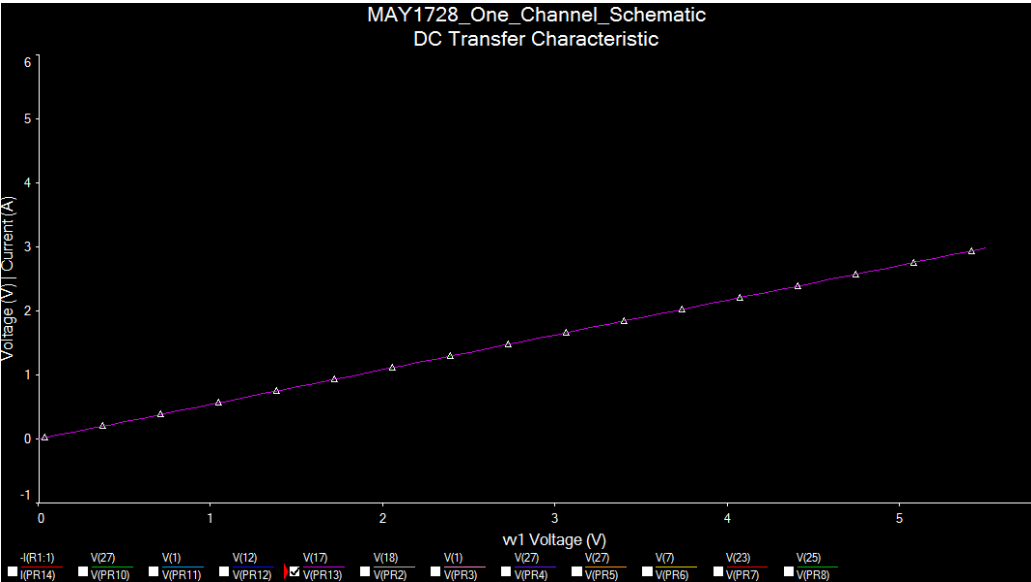


Multisim Testing: Linear Relationships



Output Voltage v. Input Voltage

Output Current v. Input Voltage



Project Cost

Item	Cost
PCB	\$36.00
Resistors (13 Total)	\$16.24
Capacitors (10 Total)	\$1.40
OPA121 (3)	\$41.58
INA163	\$7.50
Voltage Reference LM4120	\$1.91
Jumpers	\$8.63
<i>Total</i>	<i>\$113.16</i>

- OPA121 was not available for breadboard (surface mount only)
- High accuracy resistors necessary for current mirror circuit performance

10-min Q&A

part name	Digi-Key Part Number	Manufacturer Part Number	Package / Case	Price	needs	total
20k R	RNCF0603TKT20K0CT-ND	RNCF0603TKT20K0	0603 (1608 Metric)	2.15	2	4.3
2k R	P2KCTCT-ND	ERA-8ARW202V	1206 (3216 Metric)	1.77	4	7.08
200 R	P200BCCT-ND	ERA-8AEB201V	1206 (3216 Metric)	0.66	2	1.32
20 R	764-1083-1-ND	PHP00603E20R0BST1	0603 (1608 Metric)	1.62	2	3.24
931 R	P931CCT-ND	ERJ-6ENF9310V	0805 (2012 Metric)	0.1	1	0.1
1k R	311-1.00KCRCT-ND	RC0805FR-071KL	0805 (2012 Metric)	0.1	1	0.1
1.2k R	311-1.20KHRCT-ND	RC0603FR-071K2L	0603 (1608 Metric)	0.1	1	0.1
0.1u C	399-1168-1-ND	C0805C104K3RACTU	0805 (2012 Metric)	0.1	9	0.9
0.022u C	445-2674-1-ND	C2012C0G1E223J125AA	0805 (2012 Metric)	0.39	1	0.39
OPA121KU	OPA121KU-ND	OPA121KU		13.86	3	41.58
INA163UA	INA163UA-ND	INA163UA	14-SOIC (0.154", 3.90mm Width)	7.5	1	7.5
jumper	H1807-ND	A3C-2P-2DSA		0.385	13	5.005
J12	609-3713-ND	20021111-00012T4LF		0.77	2	1.54
J16	609-3715-ND	20021111-00016T4LF		0.93	1	0.93
J20	609-3717-ND	20021111-00020T4LF		1.16	1	1.16
LM4120	LM4120IM5-2.5/NOPBCT-ND	LM4120IM5-2.5/NOPB	SOT-23-5	1.91	1	1.91
					TOTAL	77.155

