Group 29 CREOL UV/VIS Spectrophotometer`

Group 29 CREOL
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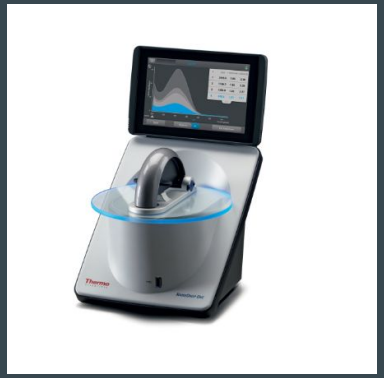
Motivation

- Answers the question “How much protein or DNA is in my sample?”
- Asked many times during a project, often between every step
- Many labs require several devices for parallel workflows
  - May not all need high accuracy
  - Cheaper options may be preferred
- Accuracy, usability, and cost all important
- Lab time is lost using and processing spectrometer data
- Create low-cost, decent accuracy device with excellent usability

Market Comparisons

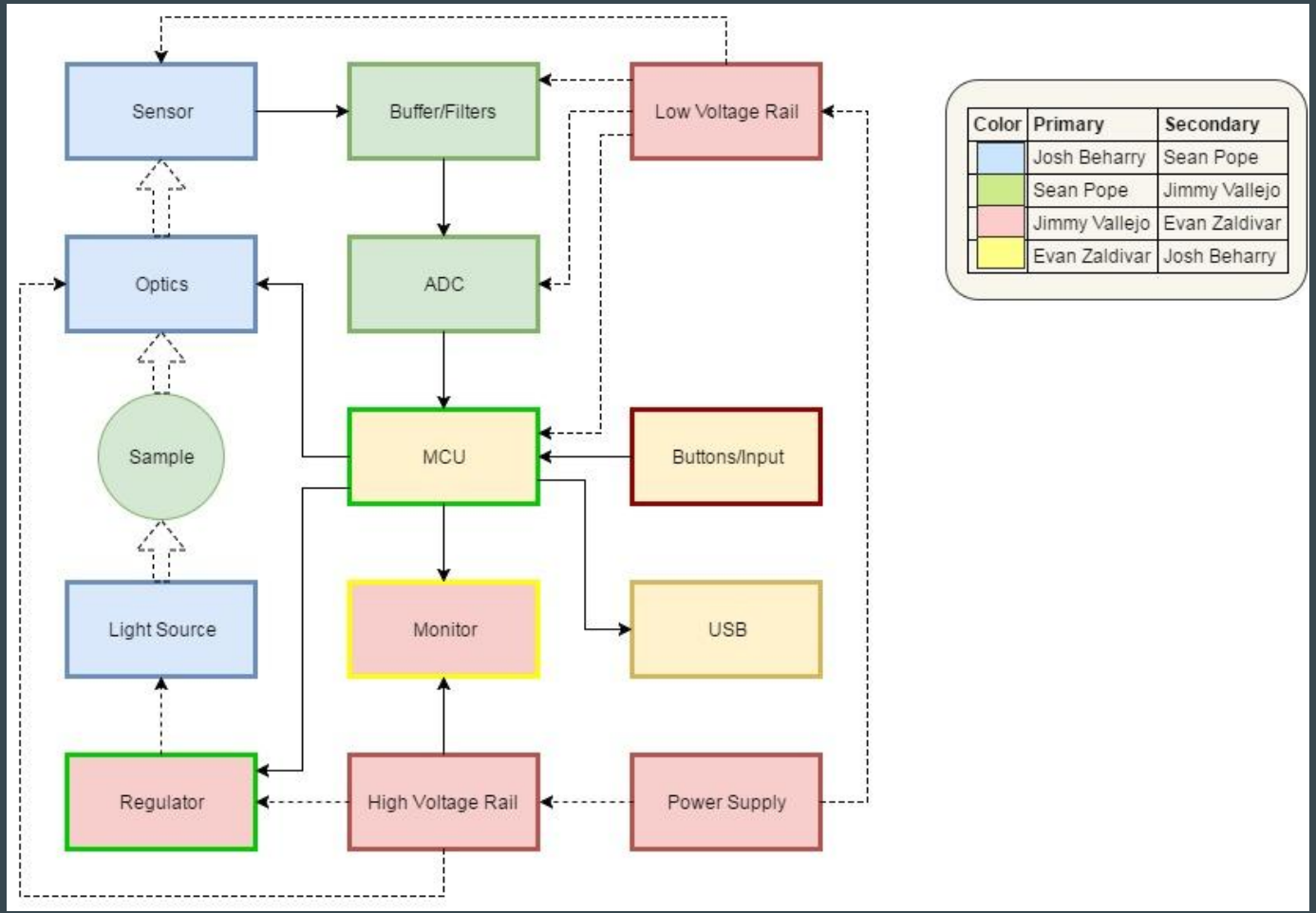


Name	SmartSpec Plus	NanoDrop One	Cary 60
Manufacturer	Bio-Rad	Thermo Scientific	Agilent
Accuracy	±0.01 AU	±0.002 AU	±0.01 AU
Interface	RS-232, 2x24 LCD	Touch-screen, USB, Wi-Fi	PC only
Price ($)	$1,500	$12,000	$600

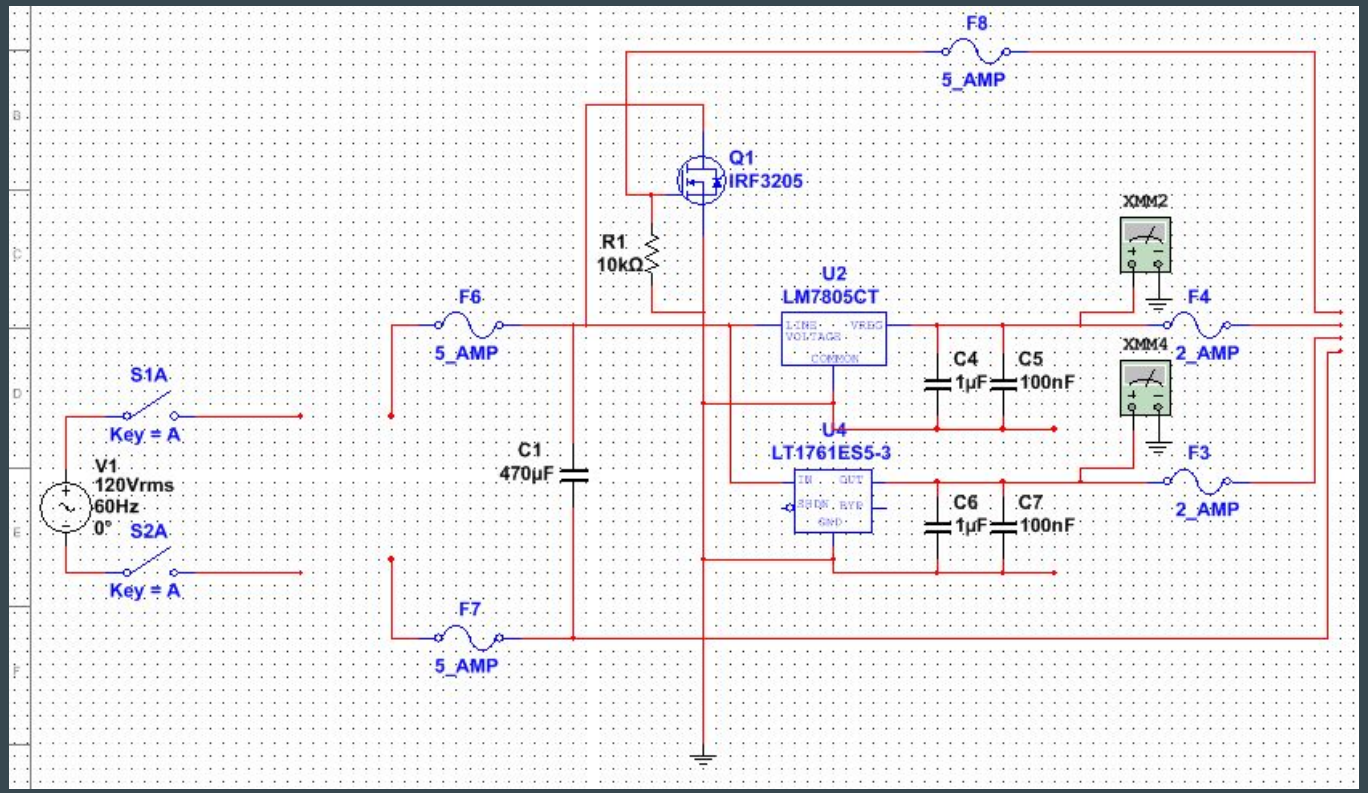
Specifications

- Fully standalone device, only requires wall outlet
- Low cost, < $2000 retail
- Output detection sensitive to within 0.1 AU
- Spectral range: 200 – 800 nm
- Wavelength accuracy: < 10 nm
- Weight: < 30 pounds
- Form factor: less than 2 ft. x 2 ft.

Block Diagram

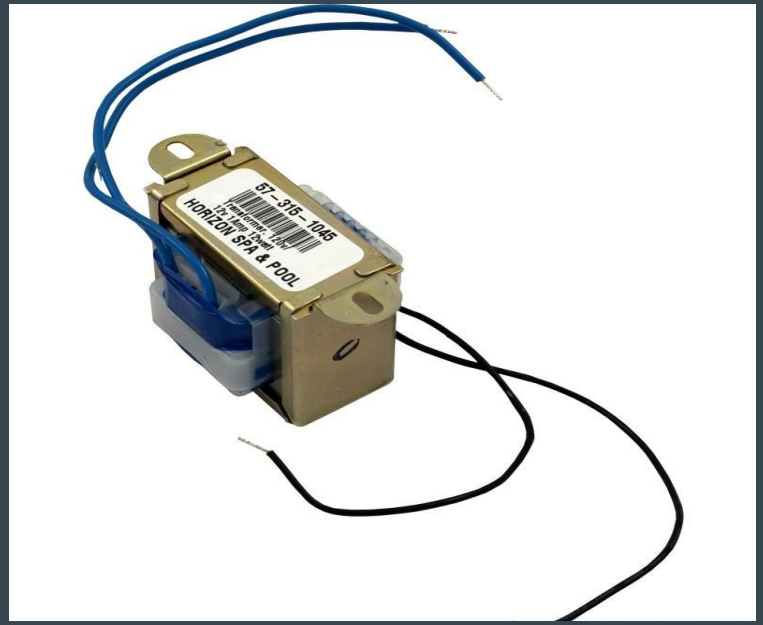


POWER SUPPLY

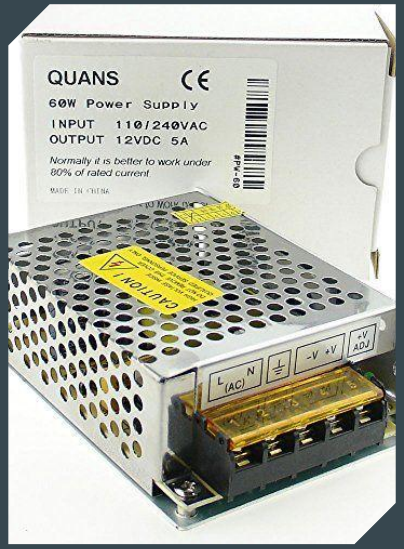


QUANS: 110V to 12V DC, 5A, 60W

Transformer 120V to 12V DC, 1A



QUANS TRANSFORMER



- Transformer is removed
- Bridge rectifier no longer needed
- Reduces the amount of rails
- Remove fuses
- LED
- Less Filter Capacitors needed
- Reduces Cost

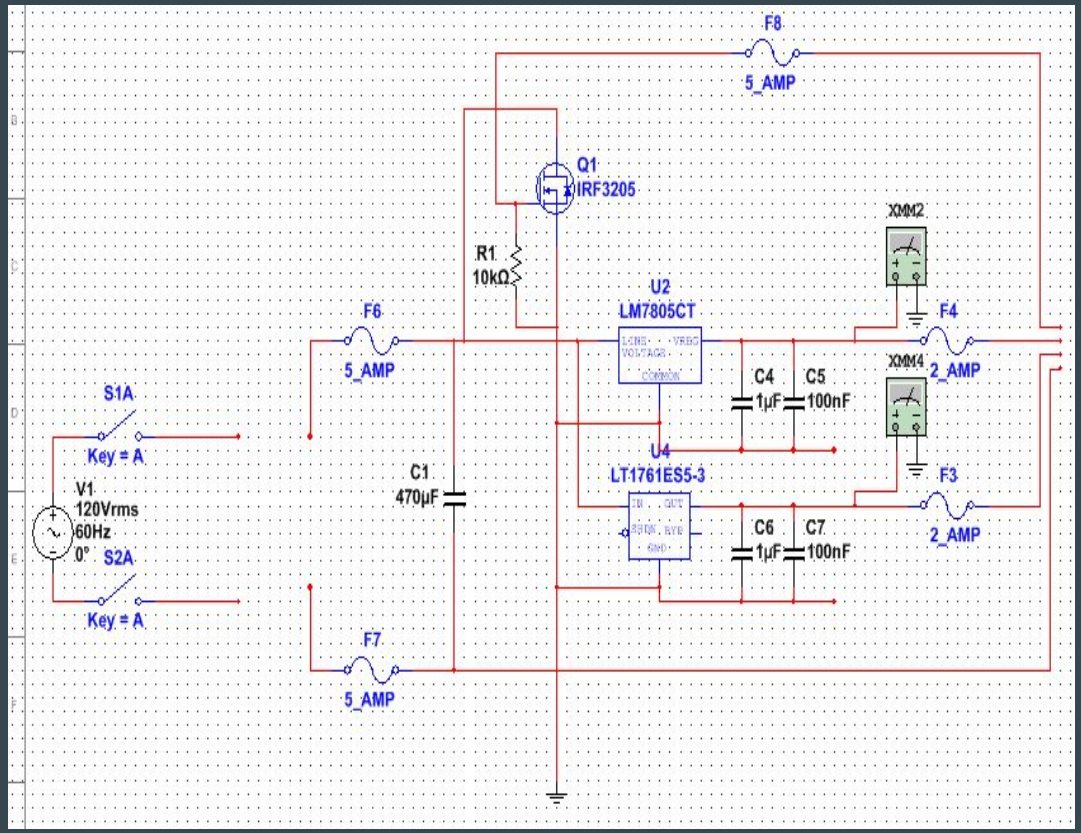
New Price

QUANS Transformer	$ 16.89
LM 7805 CT	$ 1.12
LM 1117 CT	$ 1.46
IRF 3205	$ 0.36
Blow Fuse 2A	$ 2.00
Blow Fuse 5A	$ 1.00
Total	$ 22.83

Old Price

Transformer	$ 12.80
LM 7805 CT	$ 1.12
LM 7812 CT	$ 1.81
LM 7912 CT	$ 2.27
LM 1117 CT	$ 1.46
IRF 3205	$ 0.36
Bridge Rectifier	$ 4.99
Blow Fuse 2A	$ 4.00
Blow Fuse 5A	$ 3.00
Total	$ 31.81

TOTAL PRICE REDUCTION: $ 8.98



RAILS

- 12 volts to supply light source
- 12 volts for fan, Keypad
- 5 volts supply LCD, Backlight, and Sensor Amp
- 3.3 volts is used to supply the Microcontroller, Sensor, and LCD
- -12 volt could be used to supply Sensor Amp, and initially used for Light source
- Could be removed if redesigned

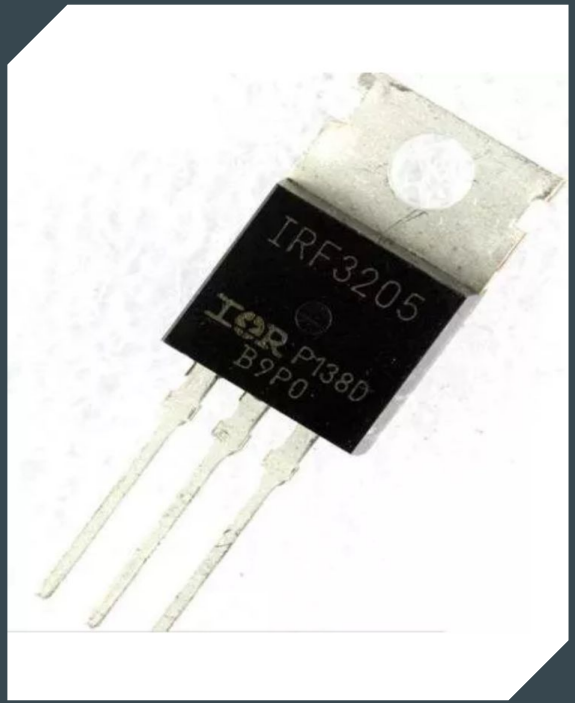
	Linear	Switching
Function	Only steps down (input voltage must be output Voltage)	Steps up and down
Efficiency	High if input to output voltage is small	High, except at low loads due to switching
Waste Heat	High if input to output voltage is small	Low
Complexity	Low only requires low value bypass capacitors	High, requires multiple components
Size	Small but larger if heat sink needed	Large at low power, but smaller when linear requires heat sink
Total Cost	Low	High, due to extra components
Ripple/Noise	Low, no ripple, low noise	High, due to ripple switching

LINEAR Regulators

- 3.3V Linear Regulator
- High, Efficiency (3.3V/5V = .66)
- Low, Power Waste ((5V-3.3V)*800mA = 1.36W)
- No Ripple
- 5V Linear Regulator
- Medium Efficiency (5V/12V = .45)
- High, Power Waste ((12V-5V)*(1A) = 7W)
- Add Heat Sink
- Low Noise/No Ripple

Digi-Key Electronics

POWER MOSFET IRF 3205



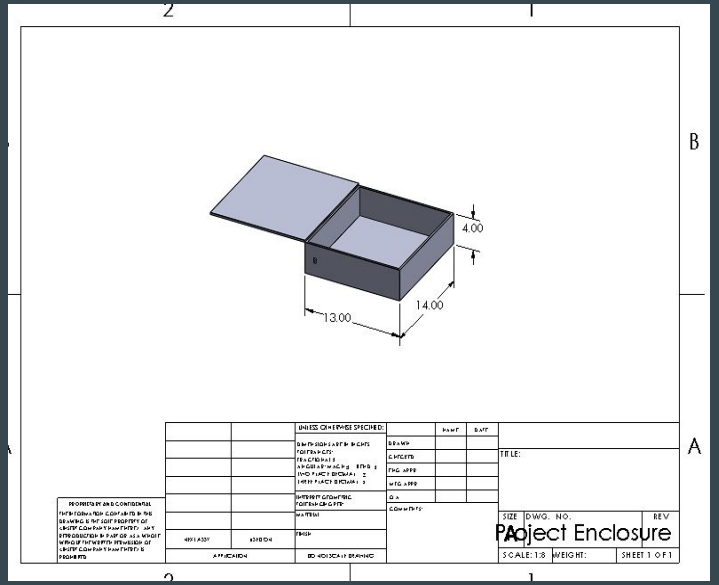
- N-Channel Mosfet
- 55v, 110A to 220
- Rds(on) = 8m ohms
- Usually 20% more - Rds(on) = 9.6m ohms
- Vgs(th) = 2 to 4 volts → on

KEYPAD

- 4x4 matrix keypad
- $16.95
- Length 2.6 inches
- Height 2.9 inches
- Width 0.4 inches

- Scorpius-22
- $59.95
- Length 4.3 inches
- Height 3 inches
- Width 0.5 inches

ENCLOSURE



I. Height = 4 inches
II. Length = 14 inches
III. Width = 13 inches
IV. 3D Printed
V. $15.00

I. Tool Box
II. Height = 5 inches
III. Length = 12.5 inches
IV. Width = 7 inches
V. $6.88

Optics Overview

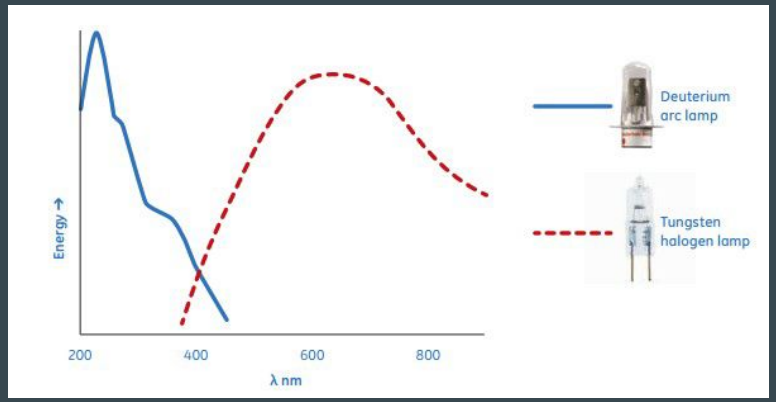
- The guts of the spectrometer

- Main Components
  - Light source
  - Diffraction grating
  - Concave mirrors
  - CCD detector

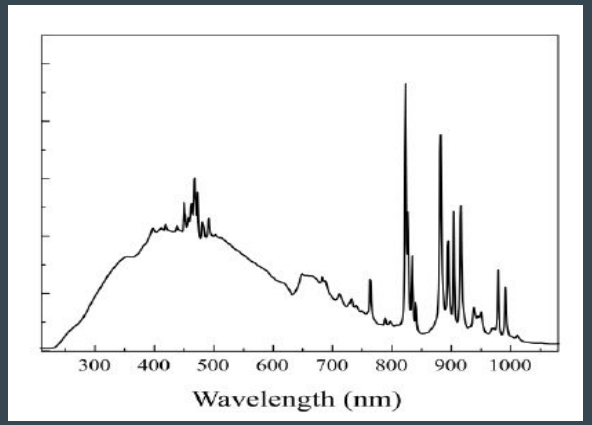
- Spectrometer Configuration

Optics: Light Source

Tungsten & Deuterium Lamps



Xenon Lamp



Requires two-source manipulation

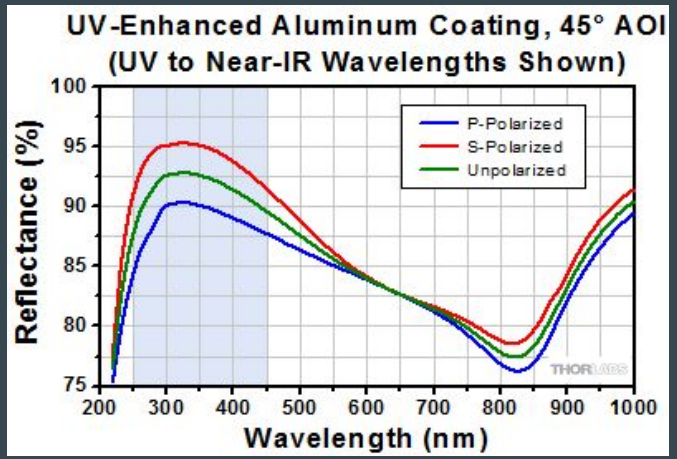
Longer lifetime than other lamps

Can cover the UV-VIS range

Selection: BulbAmerica H7 - 55 W, 12 V

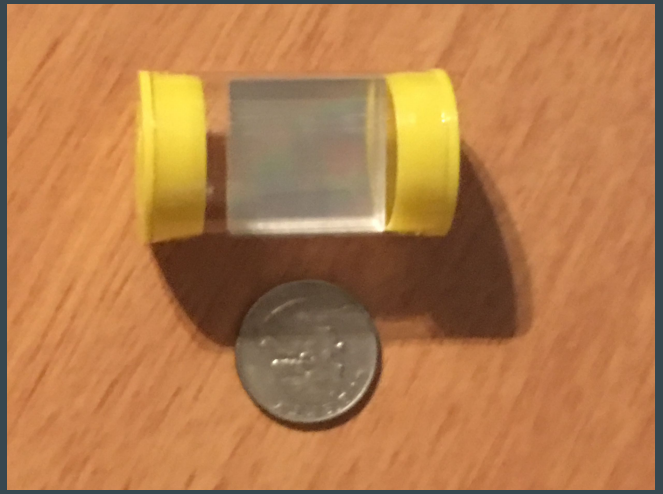
Optics: Concave mirrors

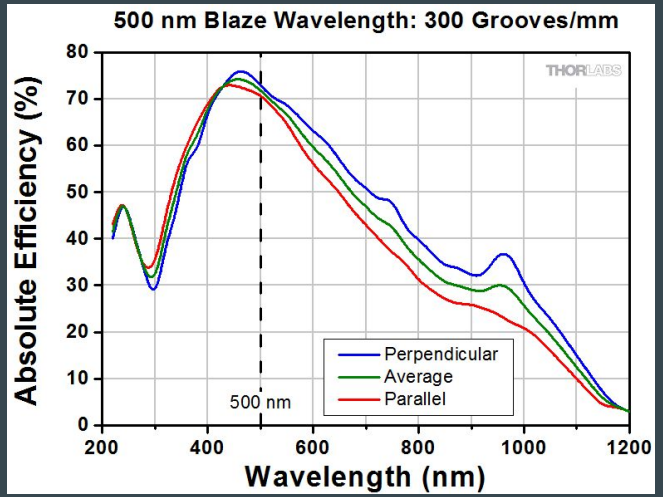
- **ThorLabs CM254-075-F01**
- 1 inch diameter
- Focal length: 75 mm
- UV-Enhanced Aluminum



Optics: Diffraction Grating

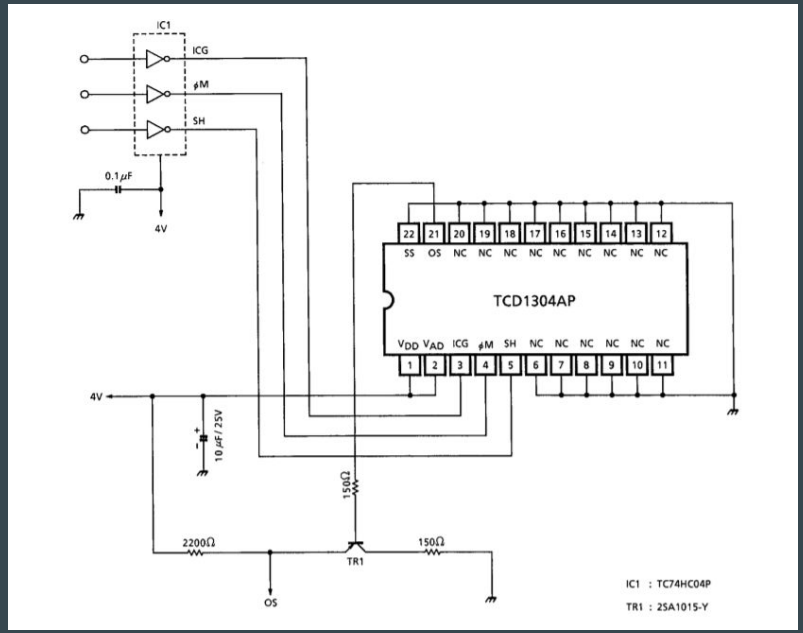
- **ThorLabs GR25-0305**
- Size: 25 mm x 25 mm x 6 mm
- Central wavelength: 500 nm
- Groove frequency: 300 grooves per mm





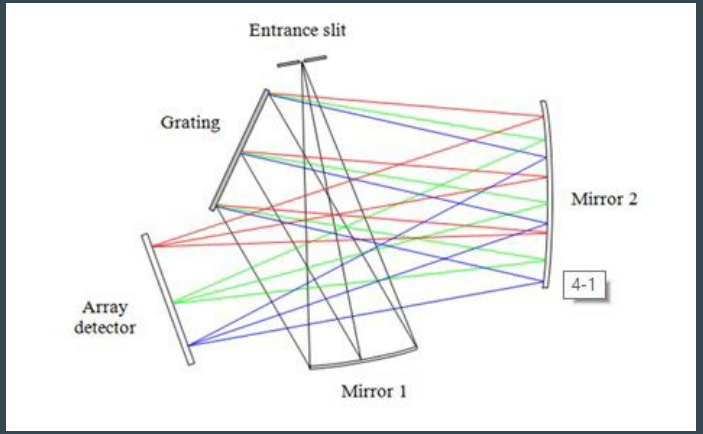
Optics: CCD Detector

- **Toshiba TCD1304AP**
- 3648 pixels
- Pixel size of 8 µm x 200 µm
- 3.3 V operating voltage
- CCD detectors are state-of-the-art

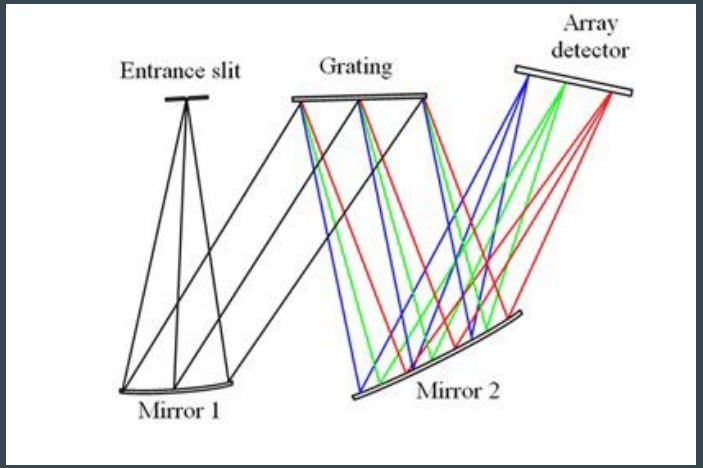


Spectrometer Configuration

- Folded Czerny-Turner
- Compact design
- Stray light problems
- For low to medium resolution applications

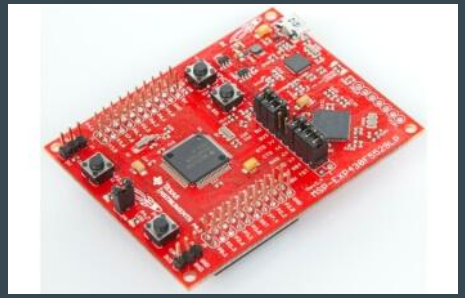


- **Unfolded Czerny-Turner**
- Alleviate stray light
- Reduce optical noise
- Space not an issue



Microcontroller Selections

- Main difference:
  - Coding environment
- More familiar with TI products.



MSP430F5529 Launchpad
Image Courtesy of TI

	GPIO	ADC	CPU	RAM (bytes)
ATxmega64A1U	78	12 bit	8 bit	4k
MSP430F5514	47	Slope - 2 bit	16 bit	6k
MSP430F5528	47	12 bit	16 bit	8k

LCD

- Kentec QVGA Display
  - 4-Wire SPI connection
  - 320x240 Resolution
  - Small but inexpensive
  - Easily compatible with Launch Pad
  - Graphics Library within Code Composer Studio
  - $24.99

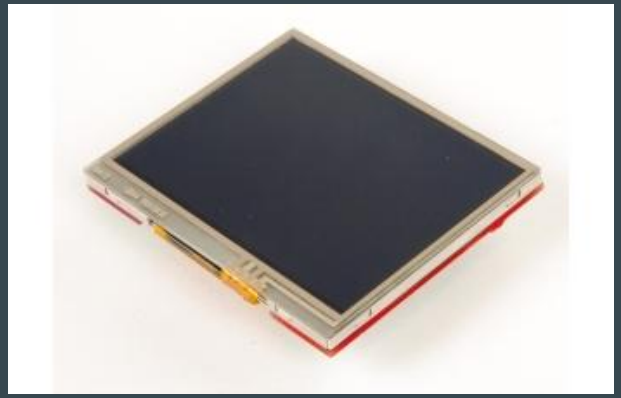
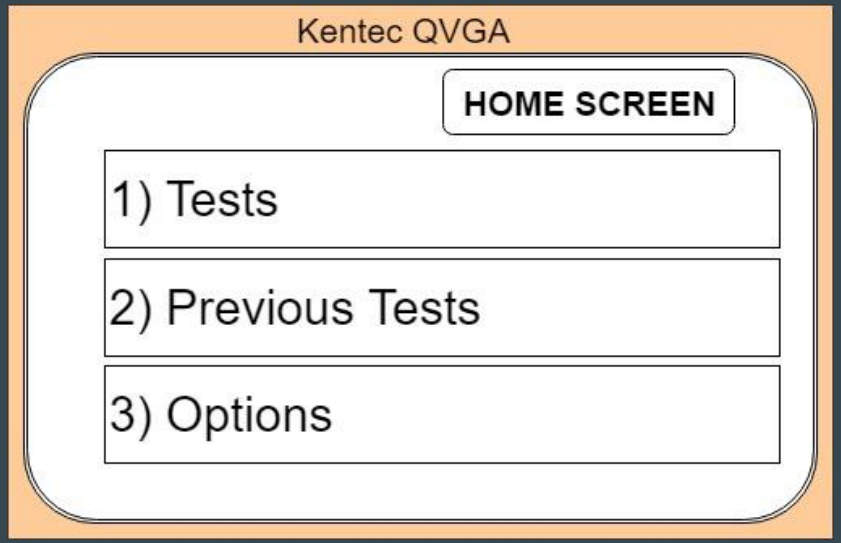
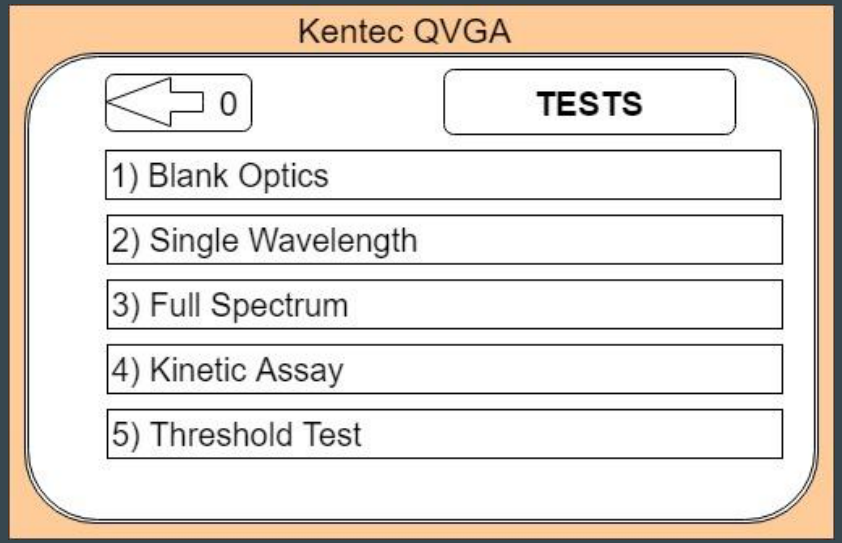


Image Courtesy of TI

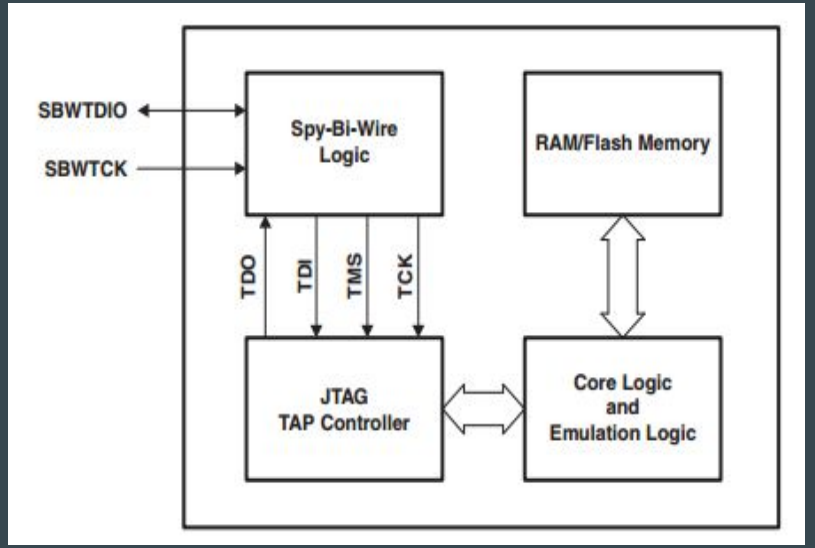
Display Design





Spy-Bi-Wire

- 2 Wire version of JTAG
  - Simpler, but slower
  - Uses less PINS
  - Backup in case USB doesn't load up automatically
  - Support for code emulation and debugging

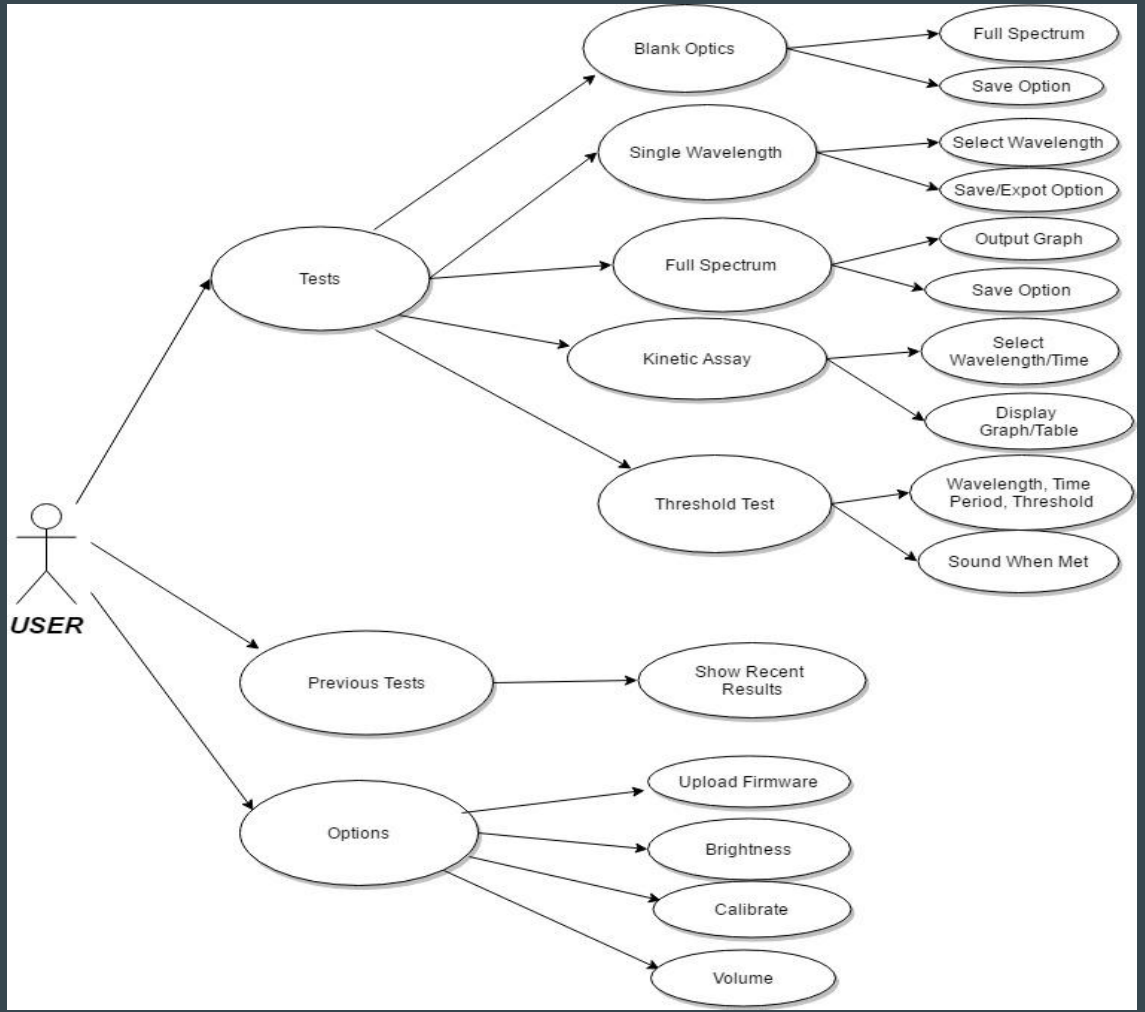


SBW Diagram from TI

Software

- Written in C through Code Composer Studio
- Will generate a graph/table
  - Given data from the tests
- Create display
  - Graphics Library within Code Composer Studio
- Will have functional Keypad used to navigate the LCD

Use Case Diagram



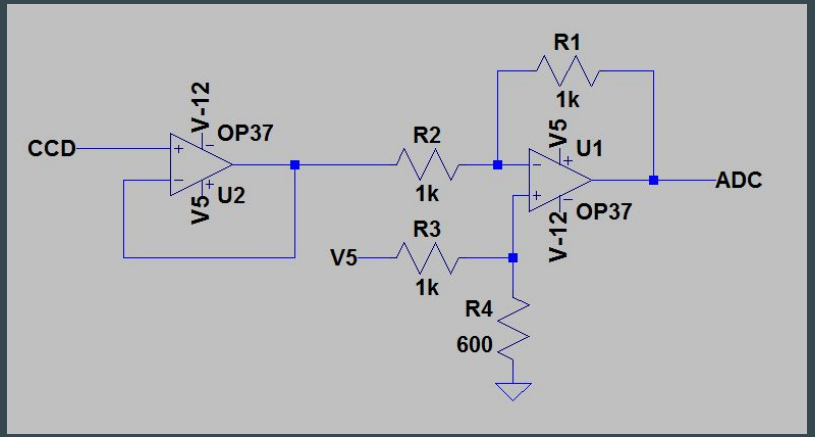
Sensor Processing

- CCD signal must be buffered and ranged
- Signal rides on a large DC offset (2.3VDC @ 3.3V supply)
  - Varies with sensor, measured from one of ours
- Saturation reduces DC level to 0.5V
- Atypical output, continuous data level
- No reference level for correlated double sampling
- 400kHz data rate
- ADC sample and hold averages pixels

CCD Output from datasheet

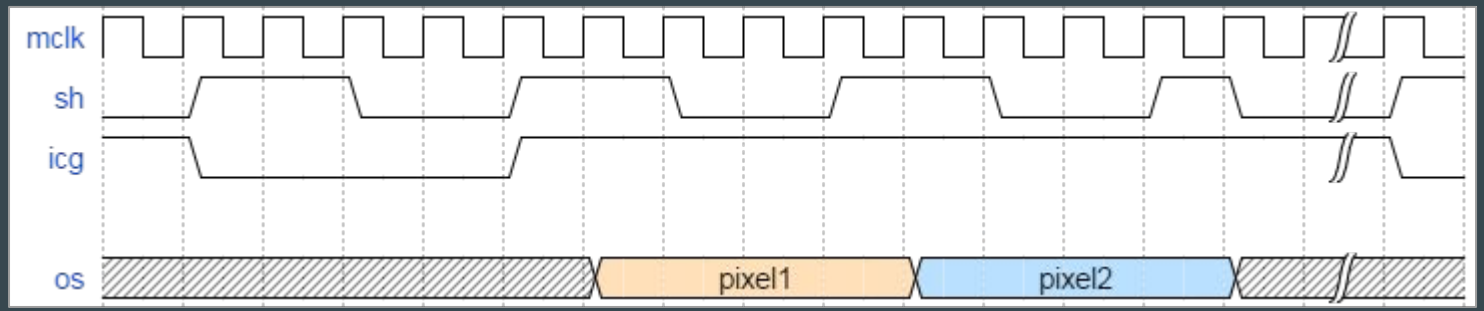
Sensor Amplifier

- TL084 - Texas Instruments - Quad op-amp
- $0.14 for quad vs $0.22 for dual amp
- Unity gain buffer for input, high input impedance
- Inverting gain/offset stage
- Trimmed gain/offset for sensor differences



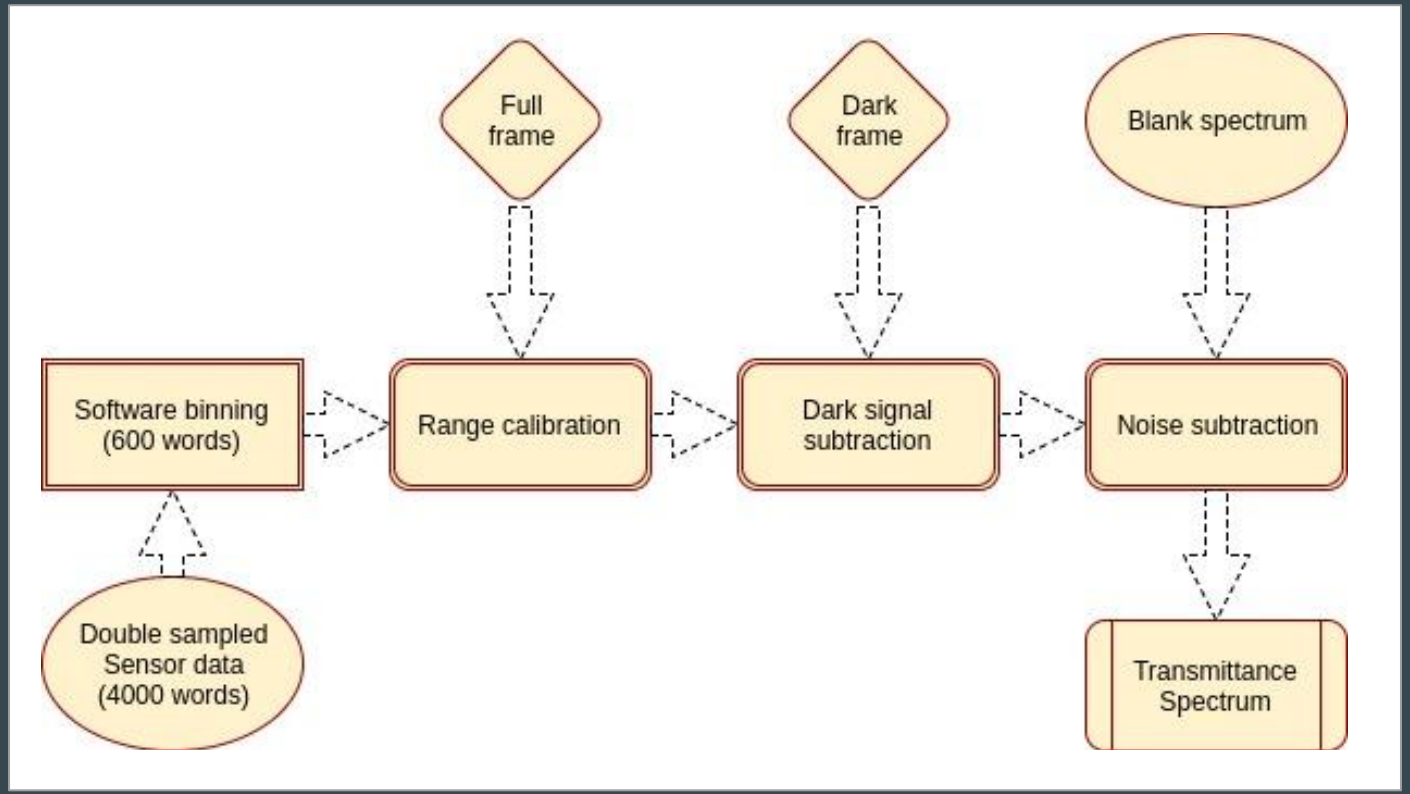
Sensor Driving

- Requires master clock for data rate
- Integration clear input to reset pixel exposure
- Shift gate input to control integration time
- Misleading datasheet for timing requirements
  - Listed ½ data rate for shift period, should be full rate

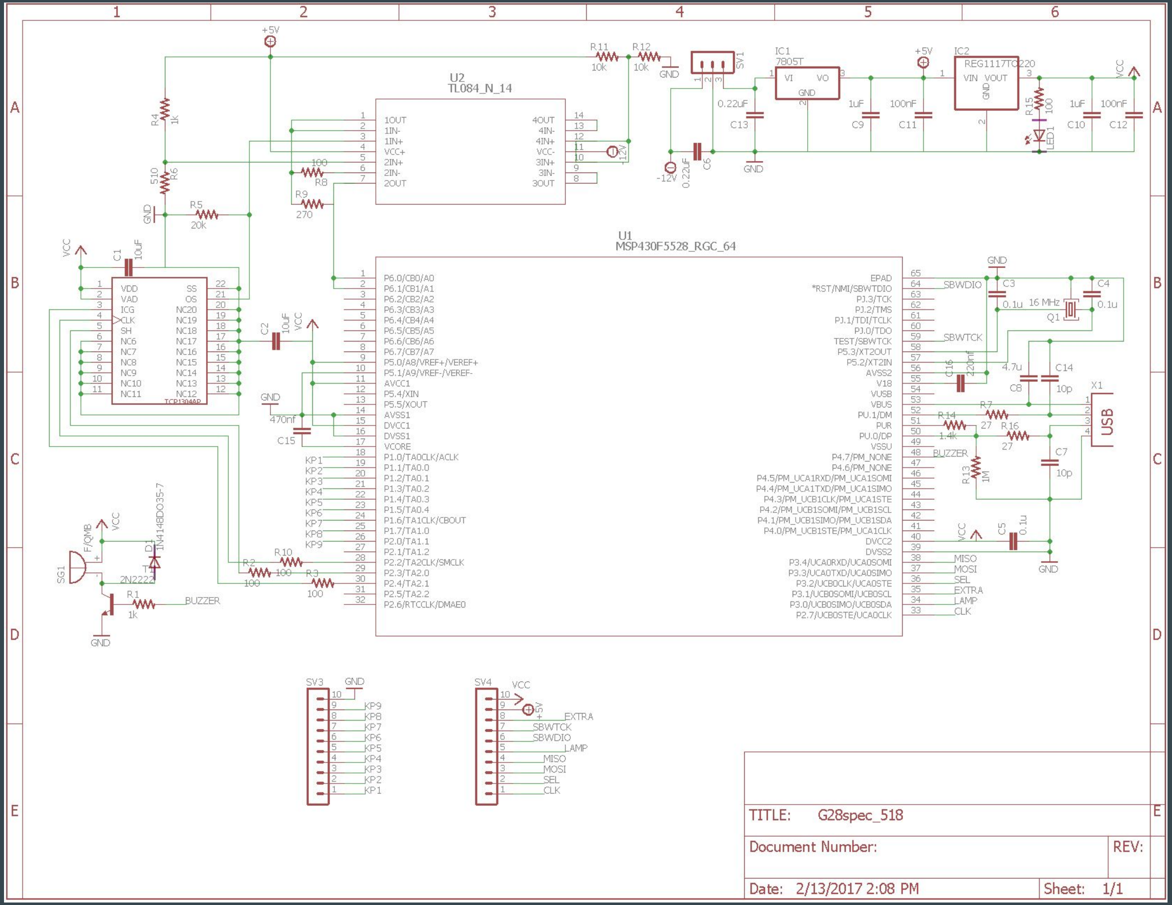


Timing parameters from MCU

Spectrum Calibration



Schematic



U2
TL084_N_14
1OUT
1IN-
1IN+
VCC+
2IN+
2IN-
2OUT
4OUT
4IN-
4IN+
VCC-
3IN+
3IN-
3OUT
U1
MSP430F5528_RGC_64
IC1
7805T
IC2
REG1117TO220
SV1
SV3
SV4
USB
X1
+5V
-12V
GND
VCC
R11 10k
R12 10k
R4 1k
R6 510
R5 20k
R8 100
R9 270
R10 100
R2 100
R3 100
R1 1k
R13 1M
R14 1.4k
R7 27
R16 27
R15 100
LED1
C1 10uF
C2 10uF
C15 470nf
C13 0.22uF
C6 0.22uF
C9 1uF
C11 100nF
C10 1uF
C12 100nF
C3 0.1u
C4 0.1u
C5 0.1u
C16 220nf
C8 4.7u
C14 10p
C7 10p
Q1 16 MHz
SG1 F/QMB
D1 1N4148DO35-7
T1 2N2222
TCD1304AP
BUZZER
SBWDIO
SBWTCK
MISO
MOSI
SEL
EXTRA
LAMP
CLK
KP1
KP2
KP3
KP4
KP5
KP6
KP7
KP8
KP9
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Date: 2/13/2017 2:08 PM
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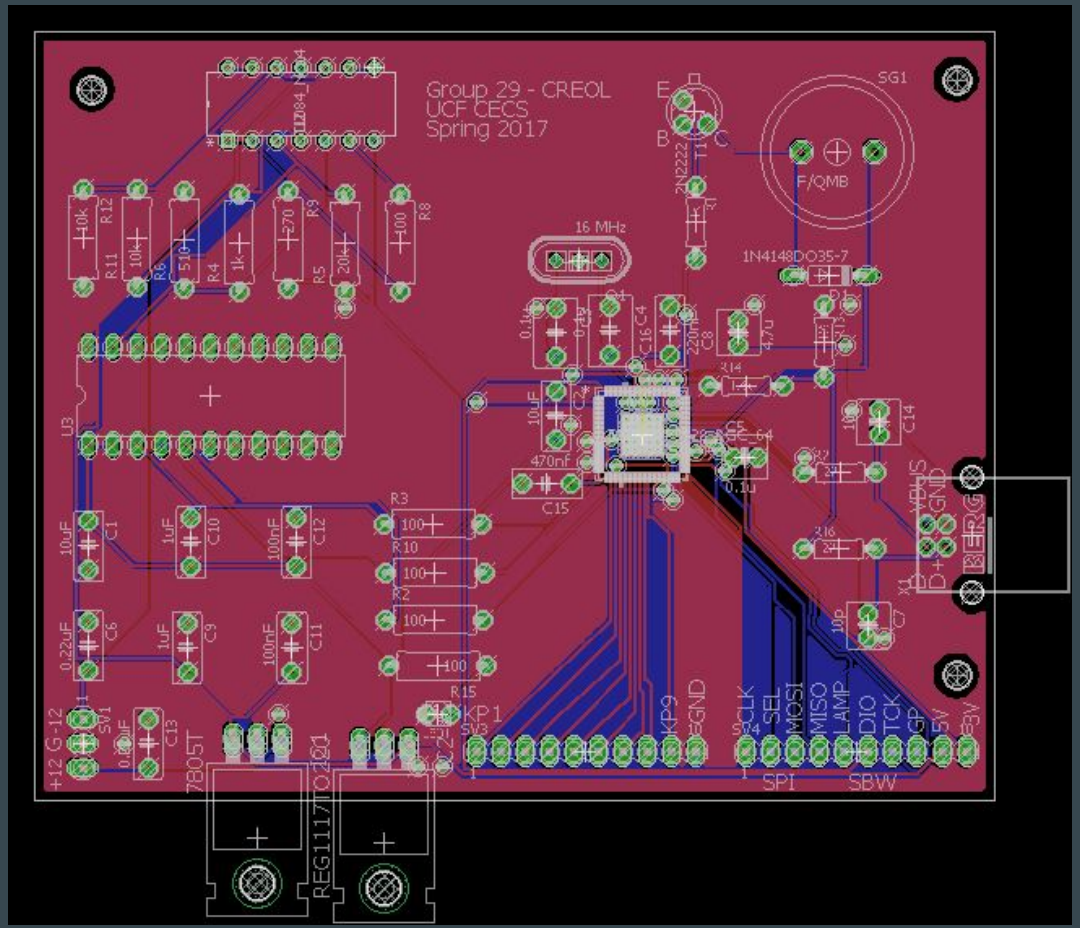
PCB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UCF CECS
Spring 2017
SG1
F/QMB
2N2222
16 MHz
1N4148DO35-7
470nF
SPI
SBW
REG1117TO201
78ST
+12 G-12
SCLK
SEL
MOSI
MISO
LAMP
TDIO
TCK
GP
5V
3V
GND
VBUS
D+
D-

Research and Development

- Multiple redesigns for feasibility/cost
  - Array detector instead of scanning monochromator
  - MSP430F5528 instead of MSP430F5529 for cost
  - Digital correlated double sampling instead of dual slope integrator for cost
  - High-wattage PSU for cheaper wideband light source
- UV light difficult to manage and measure
  - CCD likely has low UV response, but high response is expensive
  - Xenon bulbs often coated to prevent UV exposure
  - Oxygen absorbs some UV light
- Surface-mount MCU is difficult to work with
  - BGA and QFN packages only, hard to assess quality
- Optics can be very expensive
  - Mounts cost more than mirrors

Estimated and Final Costs

Component	Estimate	Actual
Microcontroller	$10	$4
LCD and Keypad	$200	$35
Motherboard	$50	$10
Optics	$1500	$227
Power supply	$30	$25
Enclosure	$20	$20*
Totals	$1810	$321

*Projected

Current Progress