2020 Robot Topic: Custom Circuit Board Design

-Or-

There's only one PDP slot left – Now what do we do?

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Custom Circuit Board Discussion

- Problem
- Data
- Design
- Board capture and layout tool
- Results and Challenges

Problem Statement

2020 robot design required multiple small 12 Volt loads

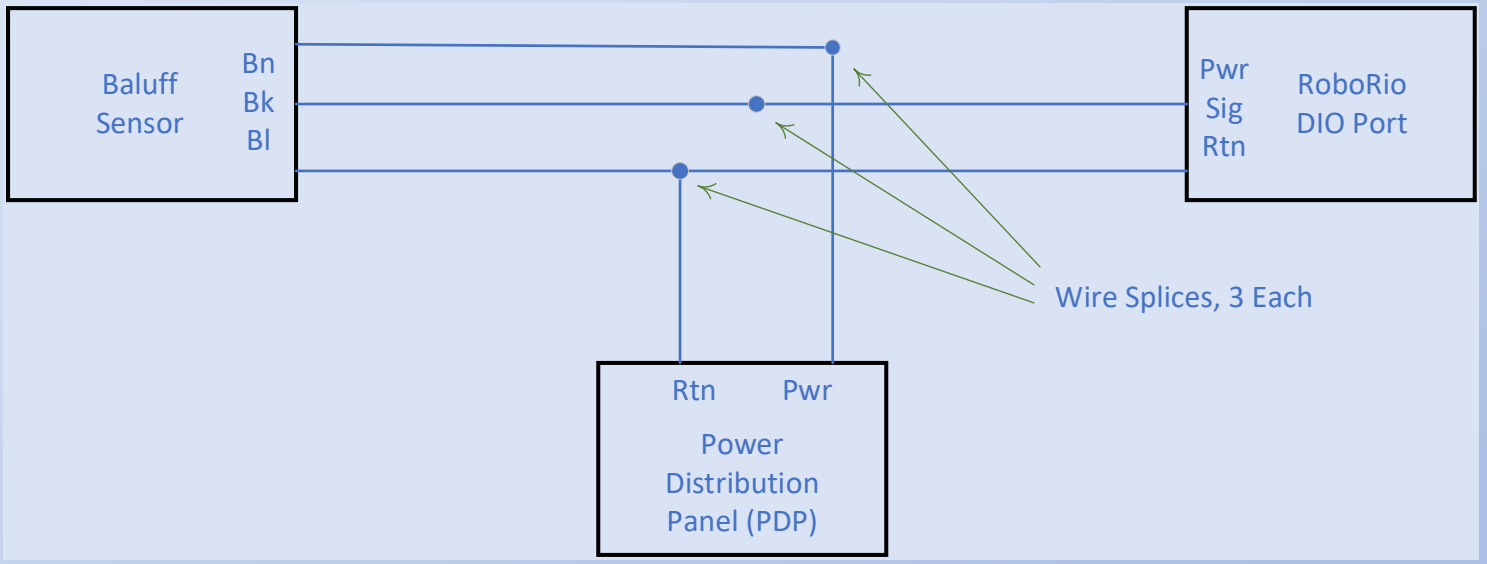
- Baluff proximity sensors (6)
- Limelight vision system
- Blinkin LED Driver (1, or more)

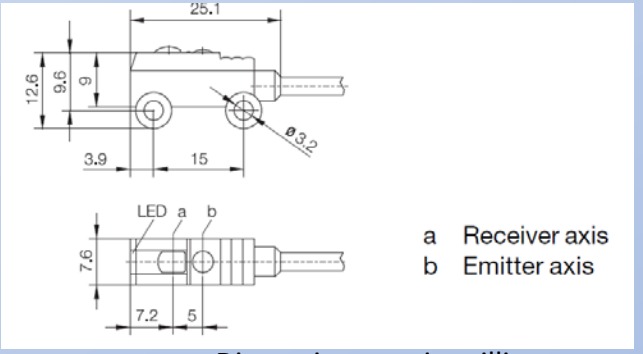
PDP provides 16 slots (services) for robot loads

- 15 are in use for motor drives
- 1 slot available to service small loads

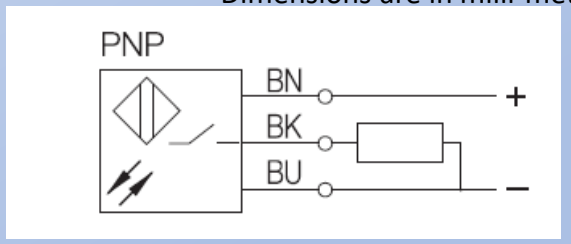
Baluff sensor details

- Sensor data sheet
  - https://www.alliedelec.com/m/d/c00d899362867bf23fa1eb0bb25f7eb1.PDF
- Sensor wiring example





Dimensions are in milli-meters



Limelight component details

- Component data:
  - https://www.andymark.com/products/limelight-2-plus
  - Or
  - https://limelightvision.io/products/limelight-2-plus

- Based upon email with Limelight technical support:

LL1, LL2 - 12V 1.3A
LL2+ - 12V 600mA

There is a slight unknown here, if the user adds an additional USB camera then you have to add its power to the overall budget.

Blinkin LED Driver details

- REV Robotics component
  - https://www.revrobotics.com/rev-11-1105/

- For 5 Volt LEDs, maximum 5 Amp load
  - 25 Watts output power
  - Assuming 80% efficiency …

5	Volt		LED drive Voltage
5	Amp		LED drive current
25	Watts	= V * I	Load power
80%			Conversion efficiency
31.25	Watts	= W / E	Supply power
12	Volts		Nominal supply Voltage
2.604	Amps	= W / V	Nominal supply current

  - Driver should operate from 2.5 Amp service, but may require a 5 Amp service

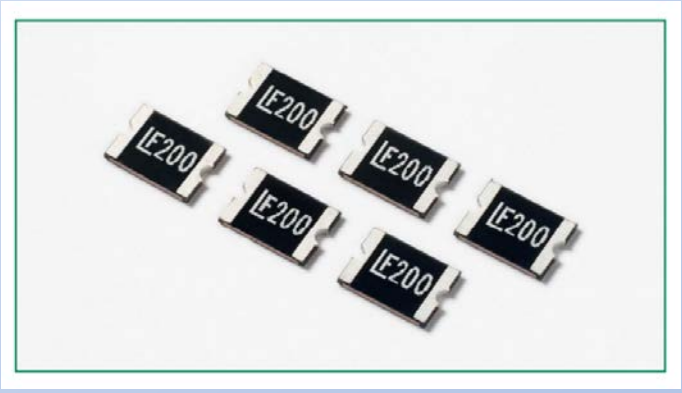
Design: Board concept

- Breakout a 12 Volt DC services to multiple loads
  - 8 loads at 0.5 Amps each (6 sensors and 2 spares)
  - 2 loads at 2.5 Amps each (Blinkin LED Driver, possibly Limelight)
  - 2 loads at 5 Amps each (Limelight in the event that 2.5 Amps isn’t enough)
- Use Weidmuller connectors for all sensor/service wiring
  - Similar to VRM and PCM connectors
- Use board mounted Anderson PowerPole connectors for board service
- Layout board such that external connections are all point-to-point
  - Use circuit board to accomplish all splices required for Baluff sensors

Connector examples

“Weidmuller connectors”

Design: Circuit protection

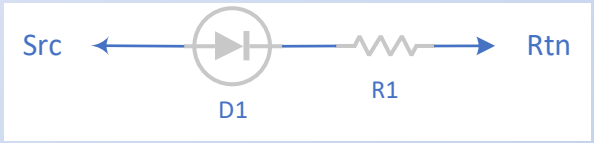


- PDP uses snap action breakers
  - Protects service wire from damage, and
  - Isolates load in the event of a fault
- Implement similar capability on breakout board
  - Use self resetting fuses
  - https://www.littelfuse.com/~/media/electronics/datasheets/resettable_ptcs/littelfuse_ptc_1812l_datasheet.pdf.pdf

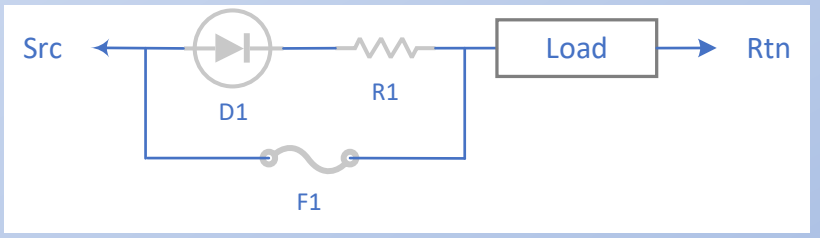
Part Number	Marking	I_{hold} (A)	I_{trip} (A)	V_{max} (Vdc)	I_{max} (A)	P_d typ. (W)	Max. Time To Trip		Resistance		Agency Approvals	
							Current (A)	Time (Sec.)	R_{min} (Ω)	R_{1max} (Ω)	c UL us	
1812L050 [1]	LF050	0.50	1.00	15	100	0.8	8.00	0.15	0.150	1.000	X	X
1812L050/30	LF050-30	0.50	1.00	30	100	0.8	8.00	0.15	0.150	1.000	X	X
1812L050/60	LF050-60	0.50	1.00	60	10	1.50	8.00	0.15	0.150	1.000	X	X
1812L075 [1]	LF075	0.75	1.50	13.2	100	0.8	8.00	0.20	0.100	0.450	X	X

Design: Power and Fault Indicators

- Objective
  - Utilize Green LED to indicate that power is on



  - Utilize Red LED to indicate a power fault (wires shorted)



Battery characteristics				
	Voltage	Vbatt	12	Volts
LED characteristics				
	Forward Voltage	Vf	2.2	Volts
	Forward current	If	20	mAmps
			0.02	Amps
Resistor calculation				
	Voltage	Vr=Vbatt-Vf	9.8	Volts
	Current	=If	0.02	Amps
	Design value	=Vr/If	490	Ohms
	Power	=If^2*R	0.196	Watts

Normal operation:

Fuse carries load current

LED is off

Faulted operation:

Fuse carries no current

LED is on

Board capture and layout

- Utilized KiCAD design tool
  - Free public domain solution

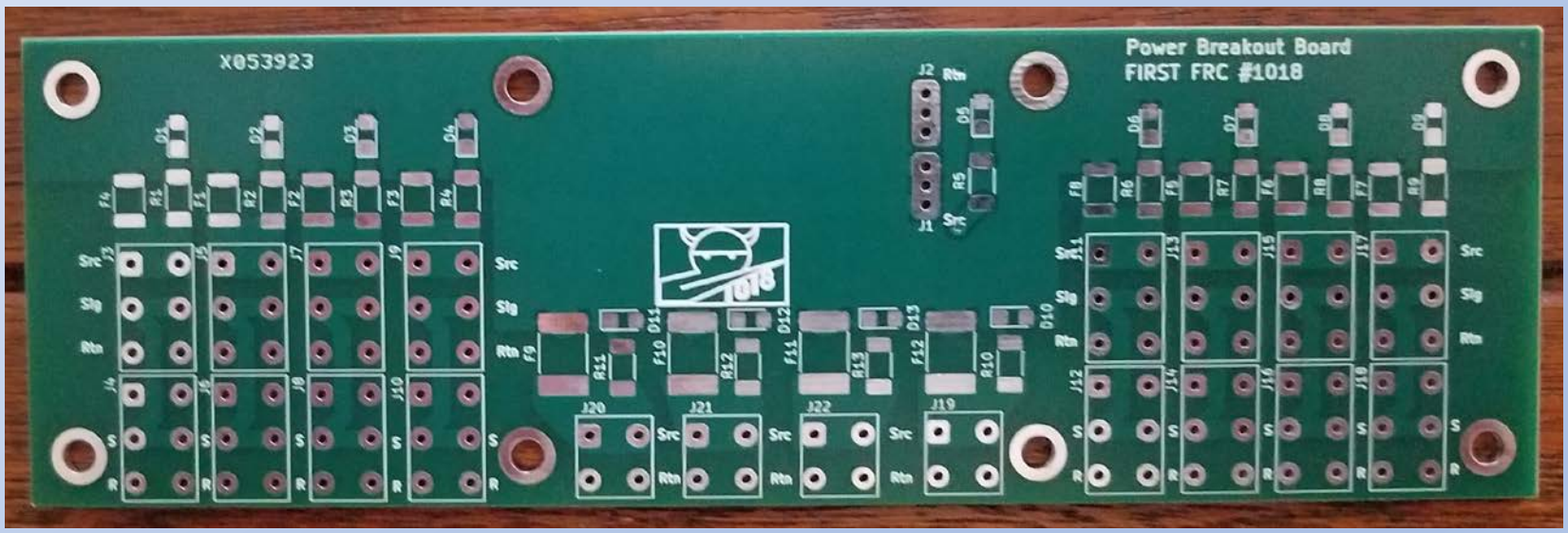
- Design Process
  - Capture any custom parts in parts library
    - Any custom parts represent the most risk
  - Capture the schematic
    - Place devices and draw connections
  - Place components and route circuits
  - Add final details and export board files

So how do I get the boards?

- I used BasicPCB
  - There are several companies that build printed circuit boards
  - This one does usually has a quick turn around but has limited flexibility
    - Watch out for shipping time!
  - https://basicpcb.com/

Result

- Fabricated 2 circuit boards
  - One for practice robot, and one for competition robot
  - Both are locked up at the school!
  - Bare circuit board (top view)



Challenges

- There were two challenges for this project:
  - Timescales, and
  - Parts

- Parts
  - You can only build the board with the parts you can get!
    - If there is a part that you want to use and it isn't in stock, you have to use something else!
  - No issue for LEDs, Resistors, Fuses …
  - Big Issue for Weidmuller connectors
  - Could only get parts that had 5.5 mm wide x 5 mm high contact spacing
    - This drove the board layout
  - Parts were all purchased before the board design was finalized.

Challenges (Concl.)

- We did not identify the need for the board until late in the build season
  - Board capture and layout ~1 day
  - Board manufacture 4 days
  - Shipping (probably took ~5 days) <<< Big problem, need to do this different!
  - Fabrication 1.5 hours

Installed and in use!