Powering the PUMA
Dec14-08

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dec1408.ece.iastate.edu

Background

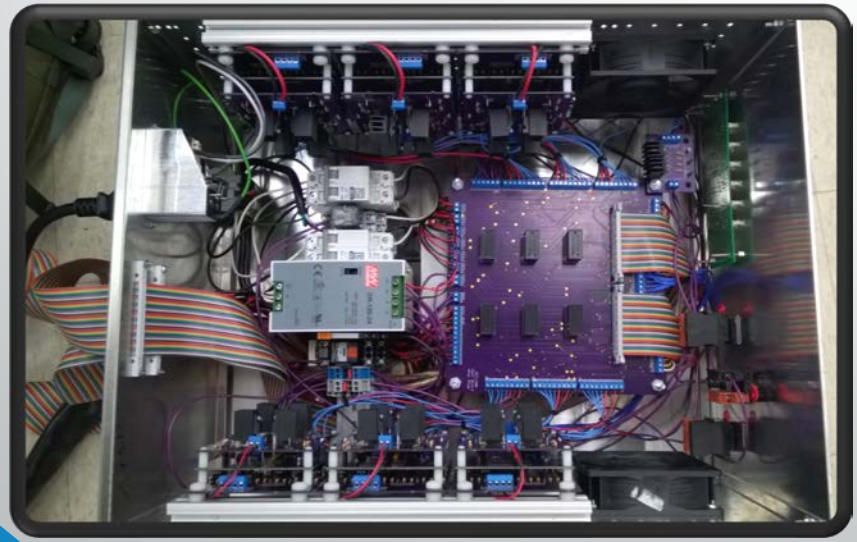
- PUMA robot
  - Lightweight
  - 6 moveable joints
  - Precise, repeatable movement
- Used in research
  - Dr. Luecke
  - Haptics & feedback
  - Kinematics

Problem

- Original controller
  - Does not provide torque control
  - Damaged beyond reasonable repair
- Client needs a new controller
  - Torque control for all 6 joints
  - Control through C code
  - Utilize existing H-bridge design

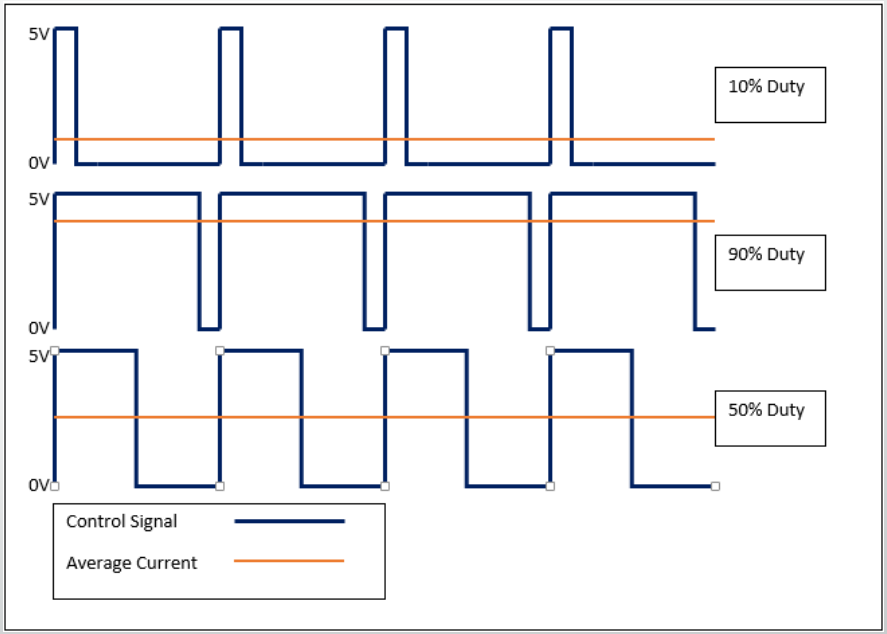
The Solution

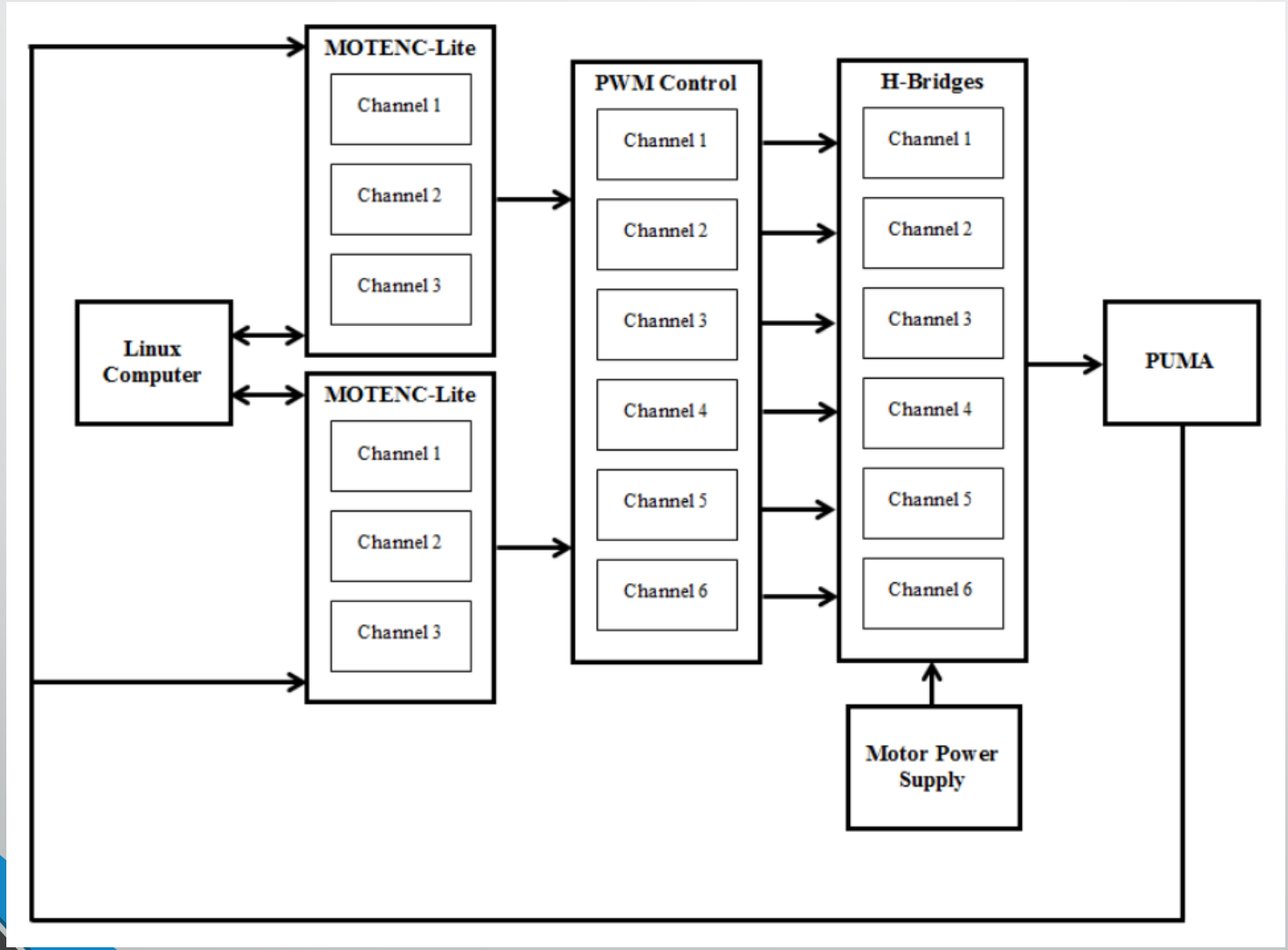
- Over 400 wire connections, 20 PCBs
- 2500 lines of code
- All packed into a 2.3 ft^3 enclosure

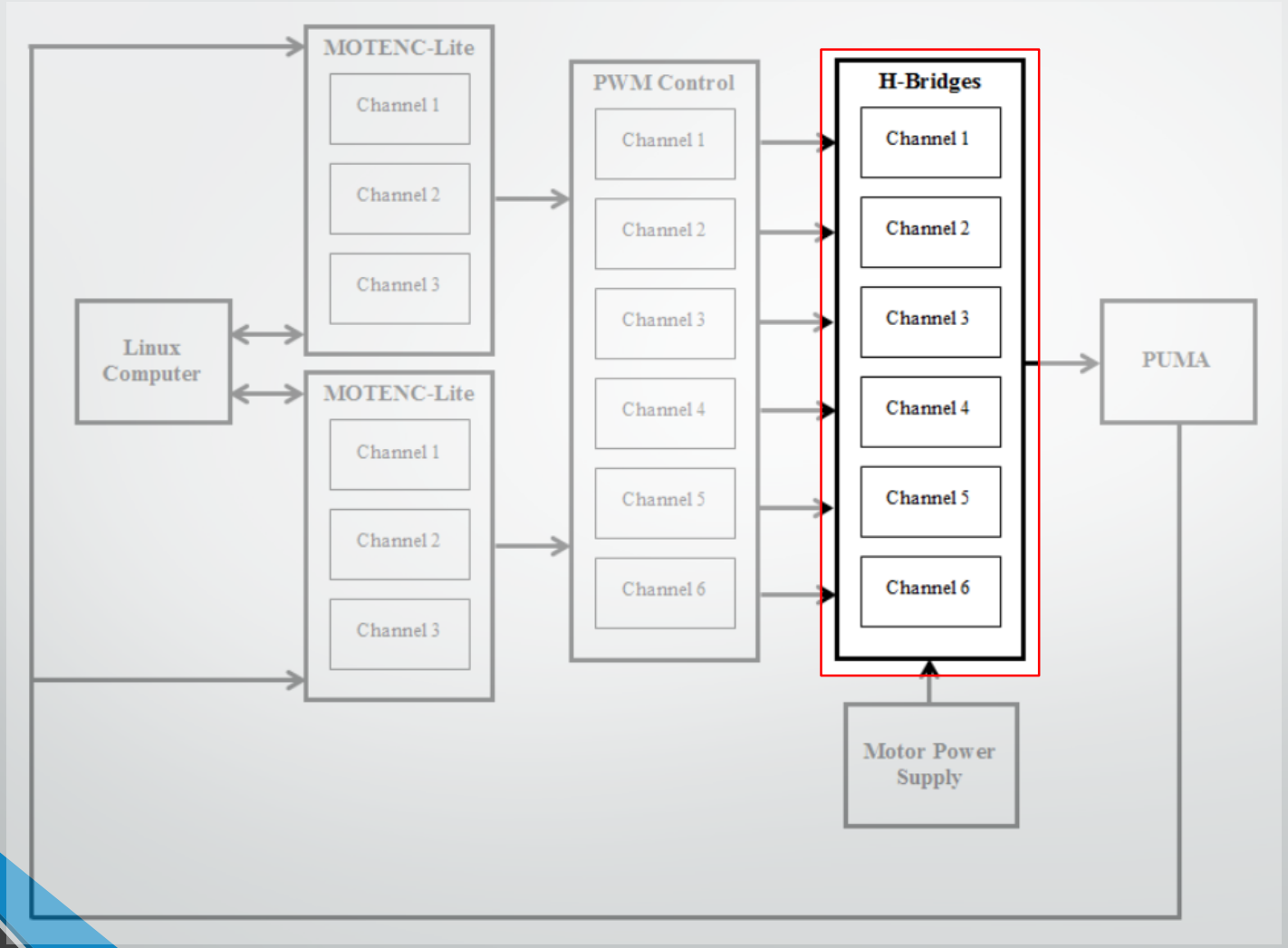


Torque Control

- $\tau = k_t * I$
  - k_t = motor torque constant
  - I = current through motor
- Can control average current with PWM signal
  - So, torque can be controlled




MOTENC-Lite
Channel 1
Channel 2
Channel 3
Linux Computer
MOTENC-Lite
Channel 1
Channel 2
Channel 3
PWM Control
Channel 1
Channel 2
Channel 3
Channel 4
Channel 5
Channel 6
H-Bridges
Channel 1
Channel 2
Channel 3
Channel 4
Channel 5
Channel 6
PUMA
Motor Power Supply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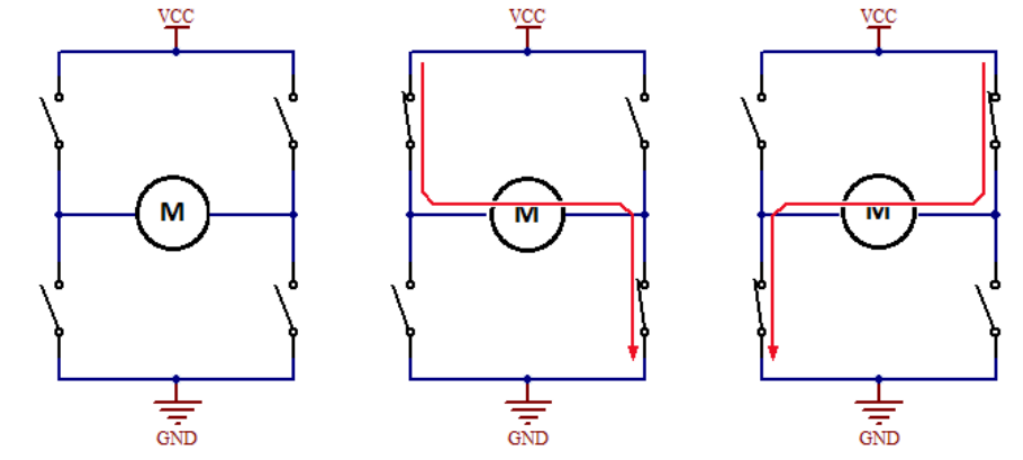
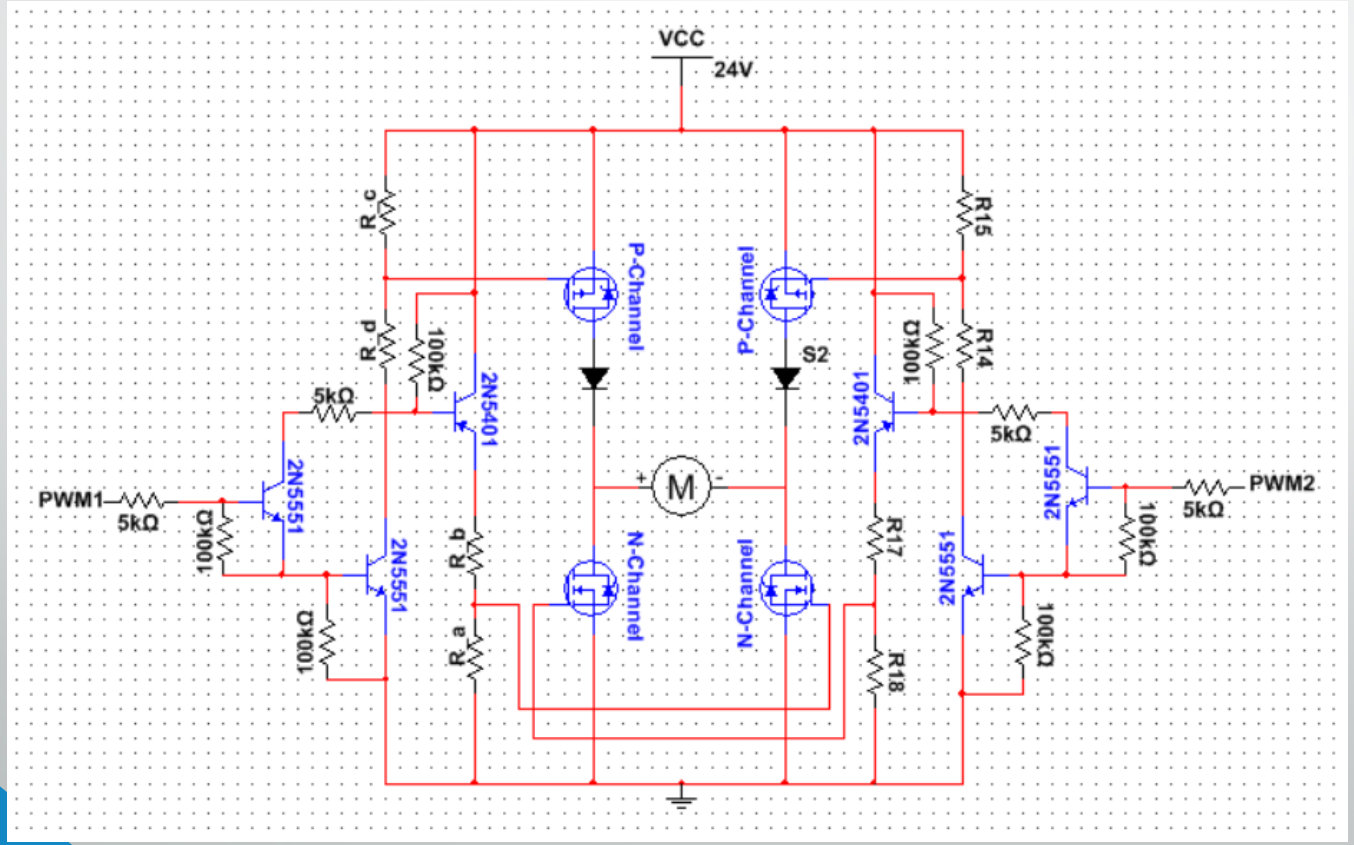
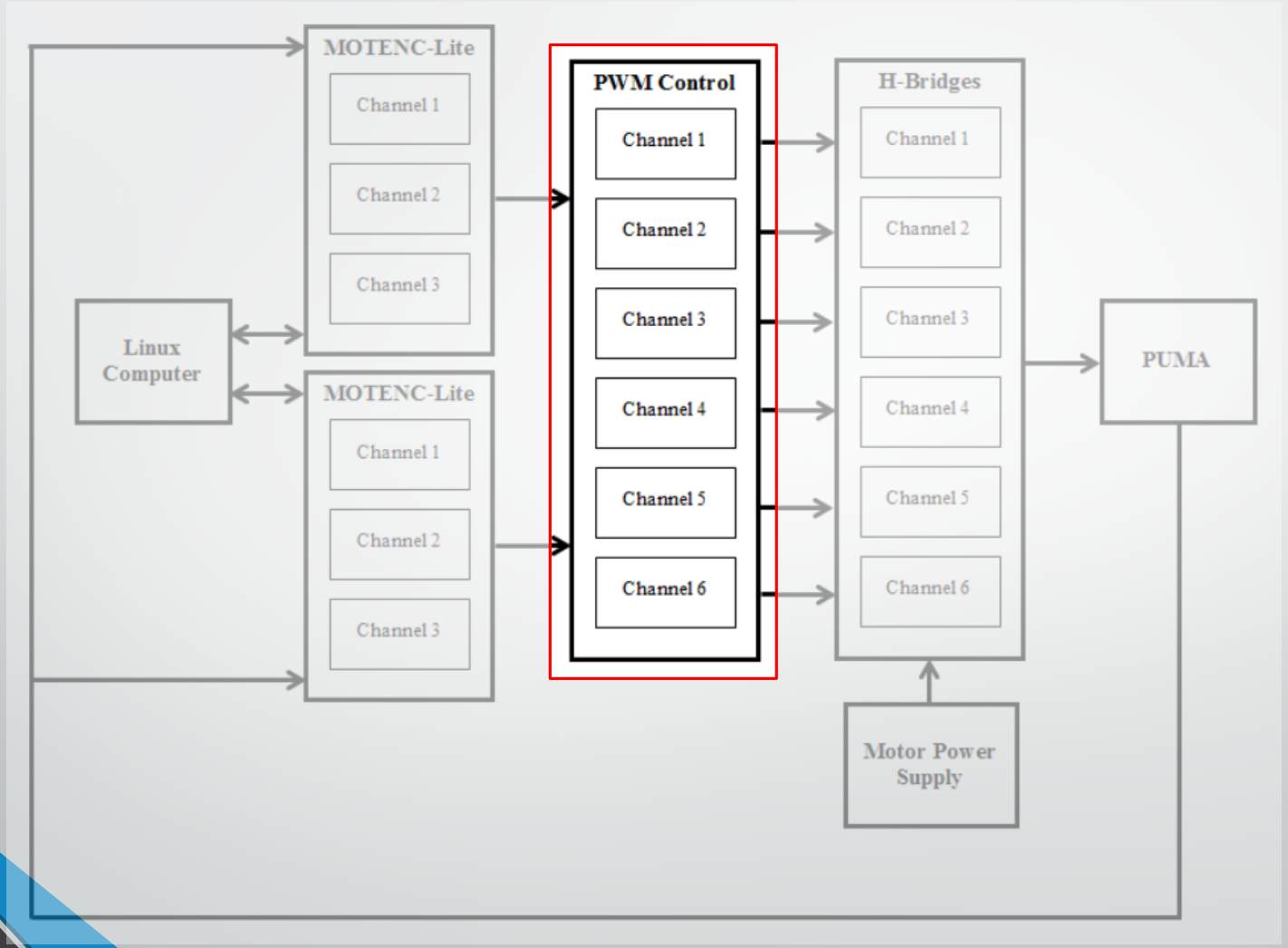
H-Bridge

- Allows bi-directional rotation of the motor
  - H-Bridge allows a path for current across the motor
- Back EMF's
  - Caused voltage polarity changes, solved with diodes



H-Bridge


VCC
24V
R_c
R_d
100kΩ
5kΩ
2N5401
2N5551
PWM1
5kΩ
100kΩ
2N5551
100kΩ
R_b
R_a
P-Channel
N-Channel
M
P-Channel
N-Channel
S2
R15
100kΩ
R14
2N5401
5kΩ
2N5551
PWM2
5kΩ
100kΩ
R17
2N5551
100kΩ
R18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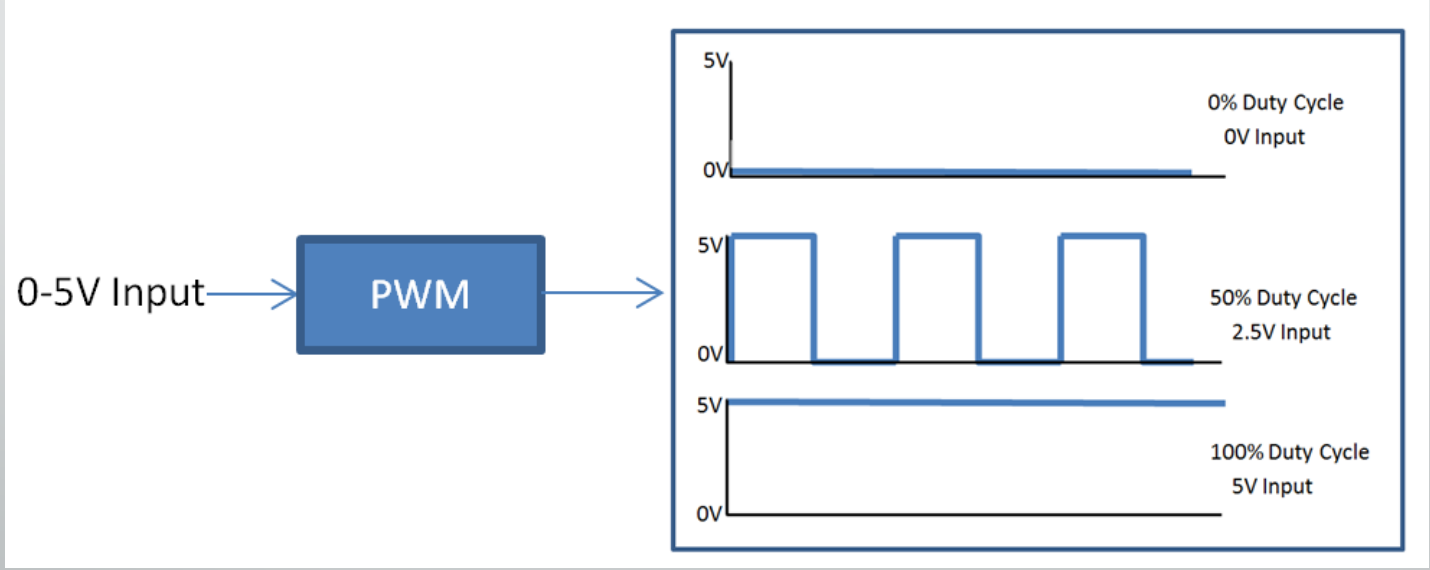
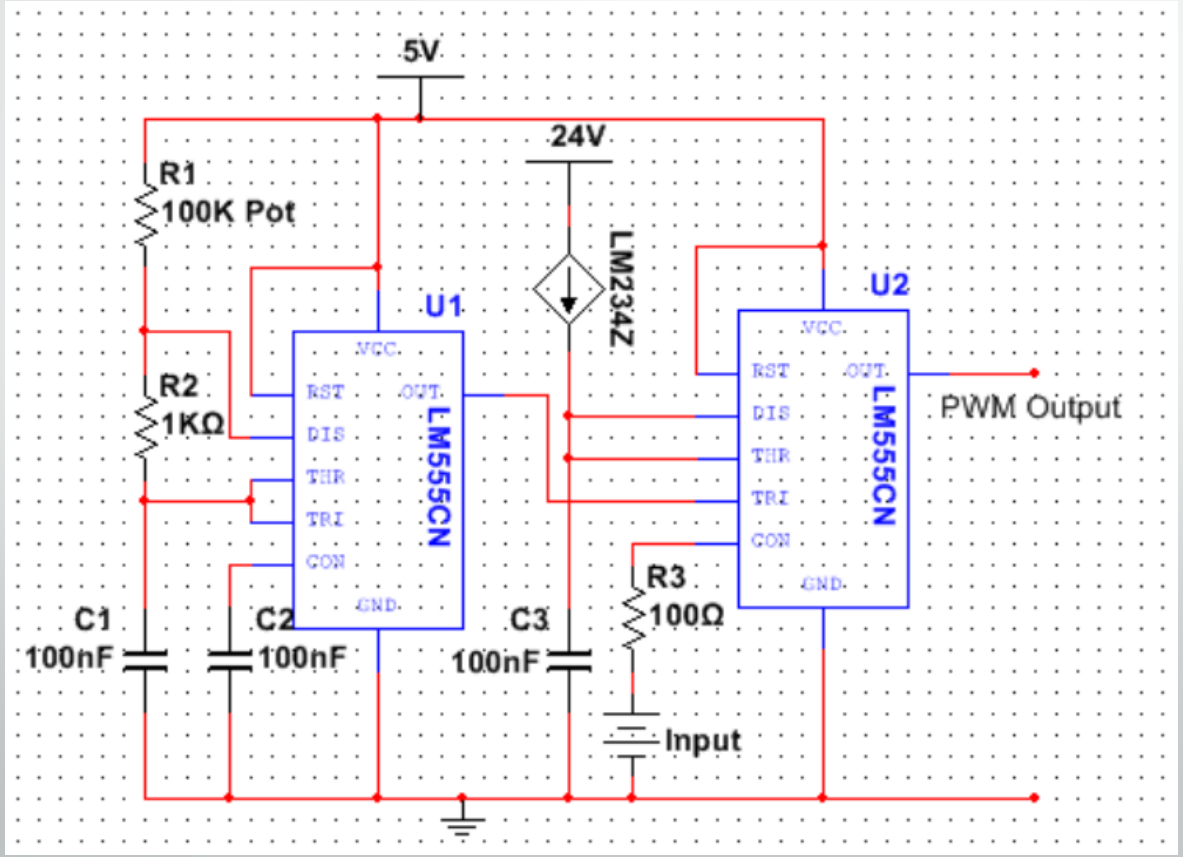
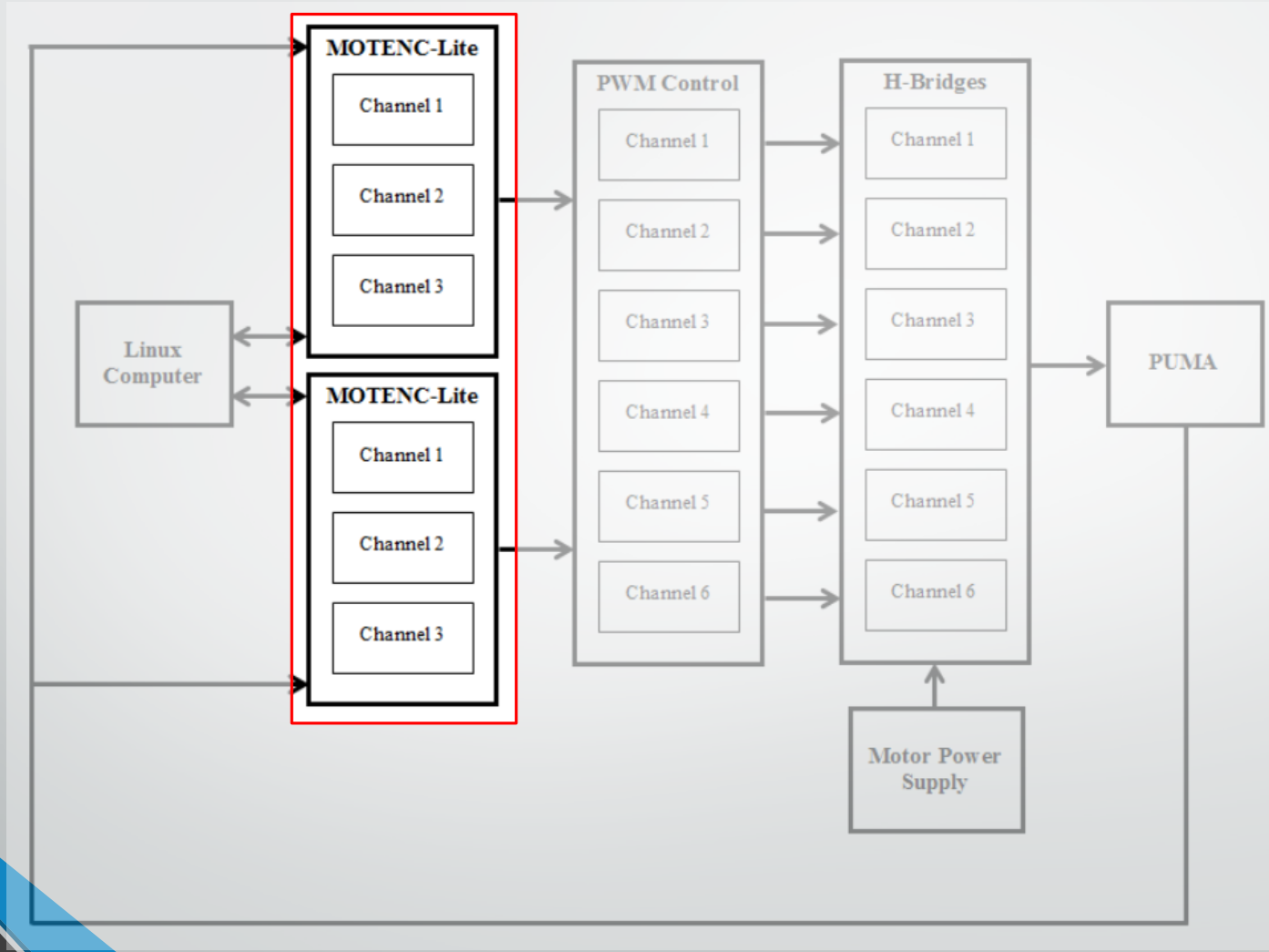
PWM Control

- PWM signals the H-Bridge to open and close
  - Duty cycle proportional to input



PWM


5V
24V
R1
100K Pot
LM234Z
U1
U2
VCC
RST
OUT
DIS
THR
TRI
CON
GND
LM555CN
R2
1KΩ
PWM Output
C1
100nF
C2
100nF
C3
100nF
R3
100Ω
Input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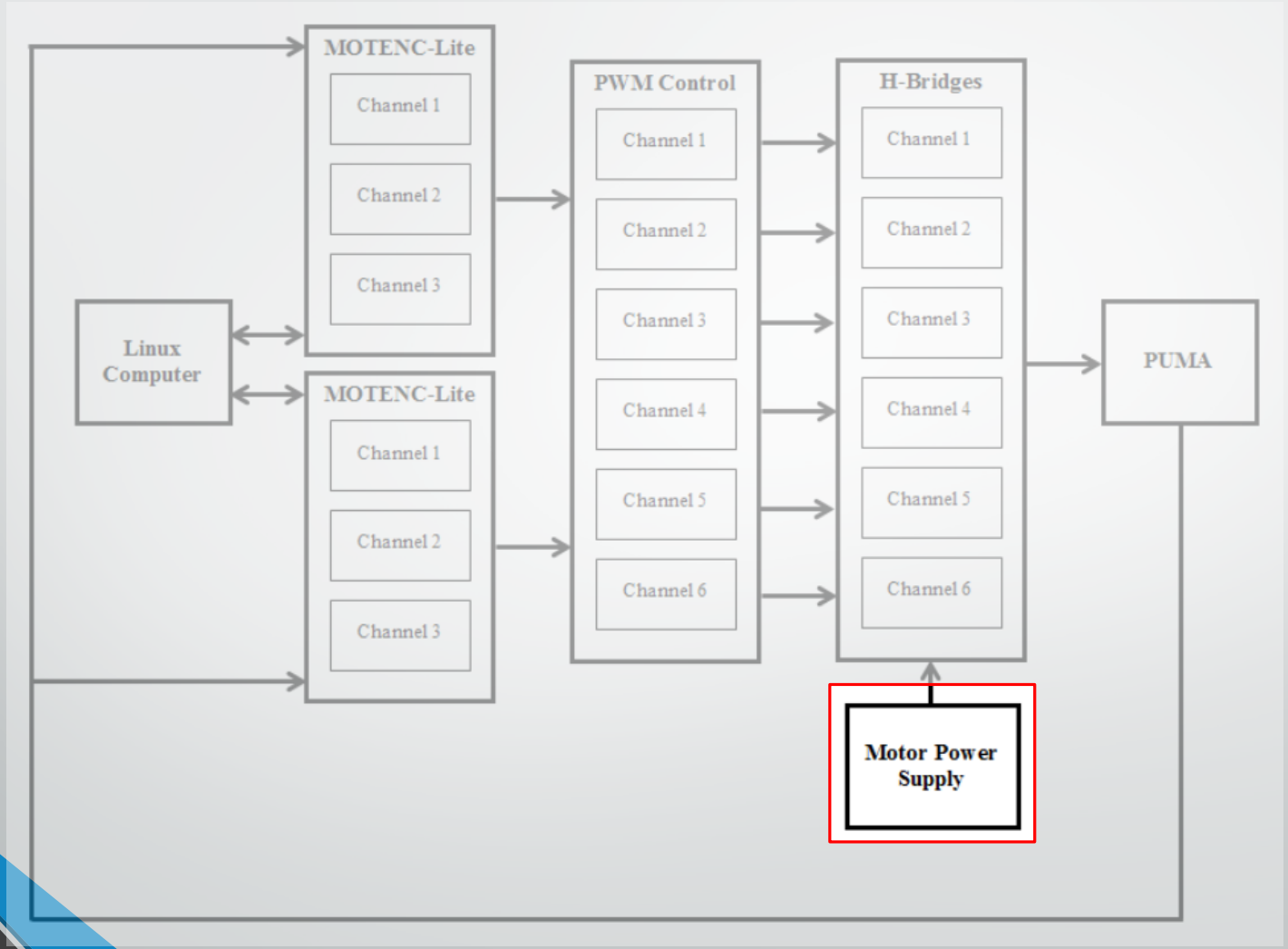
Motenc-Lite

- Industrial grade, 4-axis motion control and data acquisition card
- Provides interface to hardware/circuits
  - PWM, H-Bridge, Motors, Encoders, Pots
- Uses PCI interface
  - Controllable through code
  - Meets functional requirement
- 8 Channel DAC, ± 10 V
  - Use analog outputs to control PWM circuit
- Built-in hardware for encoders and potentiometers
  - Encoders = relative position
  - Pots = absolute position

C Code

- Collection of functions (library)
  - Search for and memory map the MOTENC cards
  - Abstracts away messy details of writing DAC, reading encoders/pots, etc.
  - Error checking prevents dangerous states
- Safe shutdown
  - Signal catching – unexpected crash/shutdown
  - Turns off all outputs, applies brake
  - Skeleton file
- Configuration file
  - Individual tuning of different PUMAs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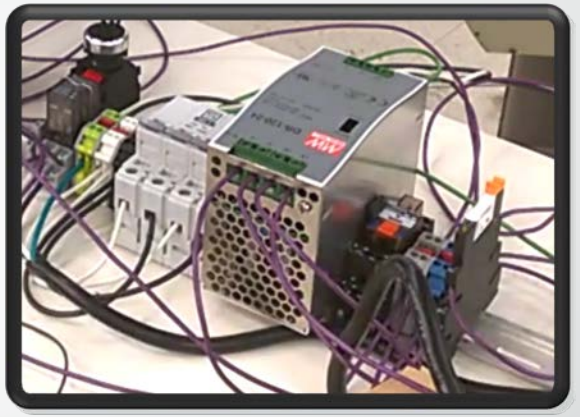
Power Delivery

- Six motors in parallel to power supply
  - Sharing current limits available power to joints
- Dedicated power modules
  - Isolates each motor
- Auxiliary circuit power
  - For remaining active devices
  - Breakers and relays protect controller from spikes/surges

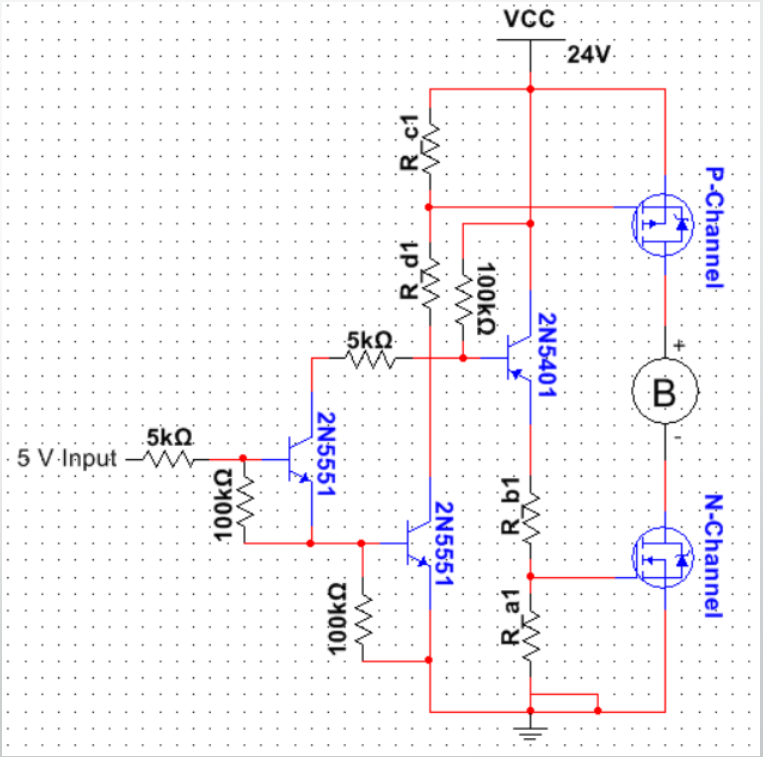


Safety Circuit

- Provides protection for PUMA and operators
  - Emergency stop
  - Motor on/off
  - Surge protection
  - Electromechanical brake indicator
    - Indicates PUMA in motion

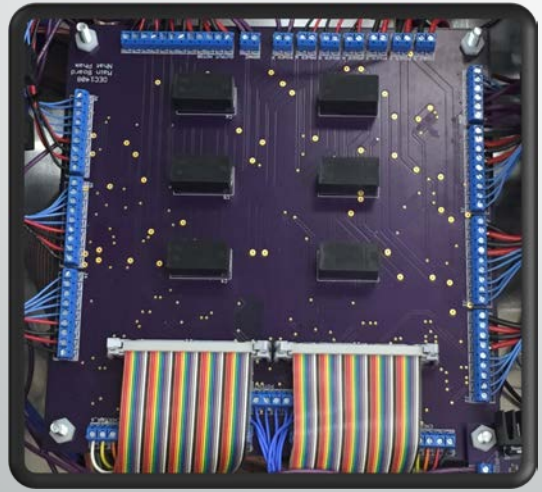
Electromagnetic Brake

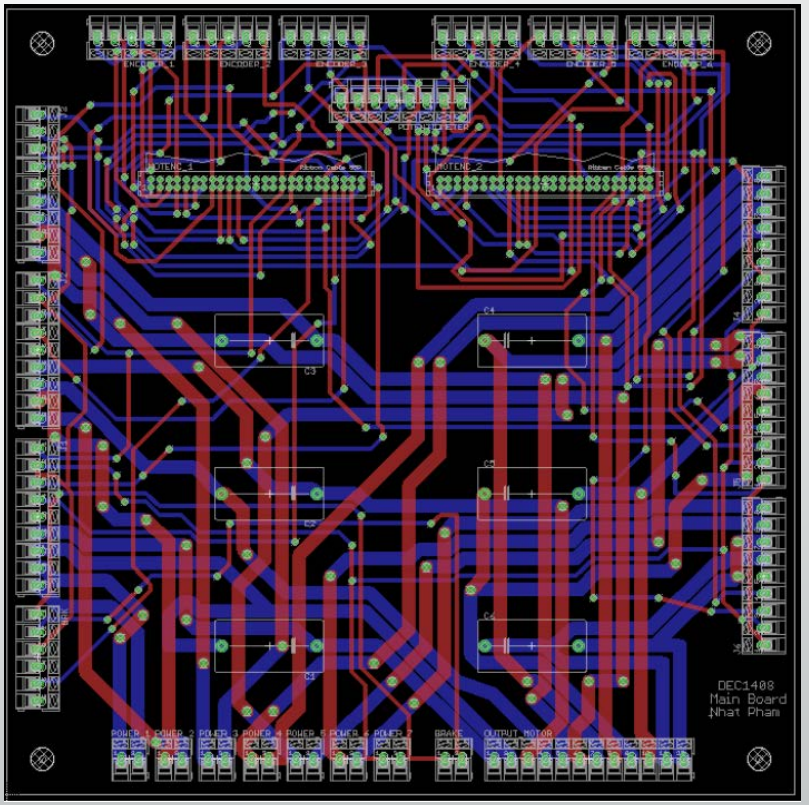
- Locks lower three joints for safety
- Half H-Bridge w/ 100% duty
- Cruical that brake is applied:
  - Program crashes
  - E-Stop pressed



Main Board

- > 100 connections
- Bypass capacitors
  - Smooth voltage across motors





Test Plan

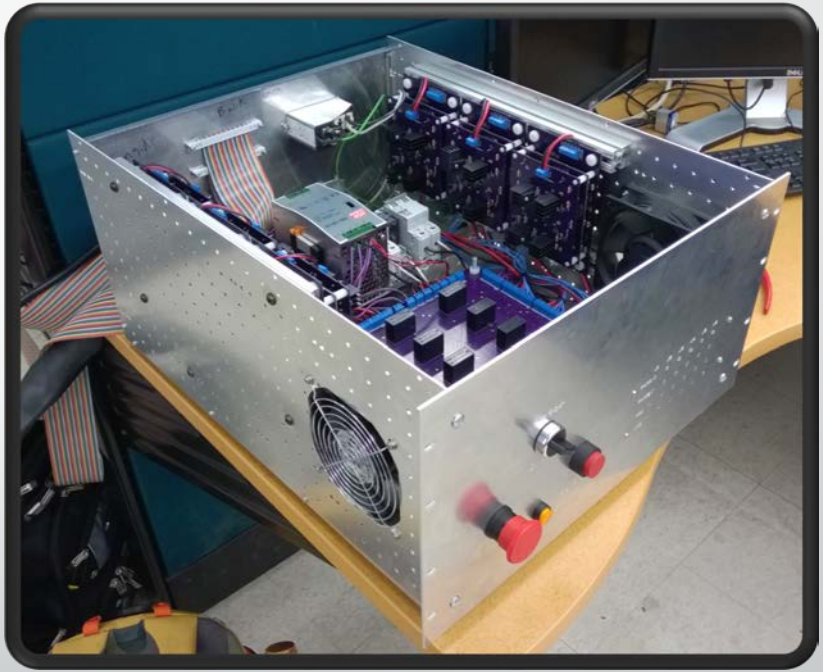
- Ensure that each subsystem works as designed
  - Test circuits individually
- Ensure that subsystems work in circuit
  - Combine circuits one at a time
- Ensure code works with robot
  - Full system test

Demo Video

http://dec1408.ece.iastate.edu/media/videos/demo.mp4

Enclosure

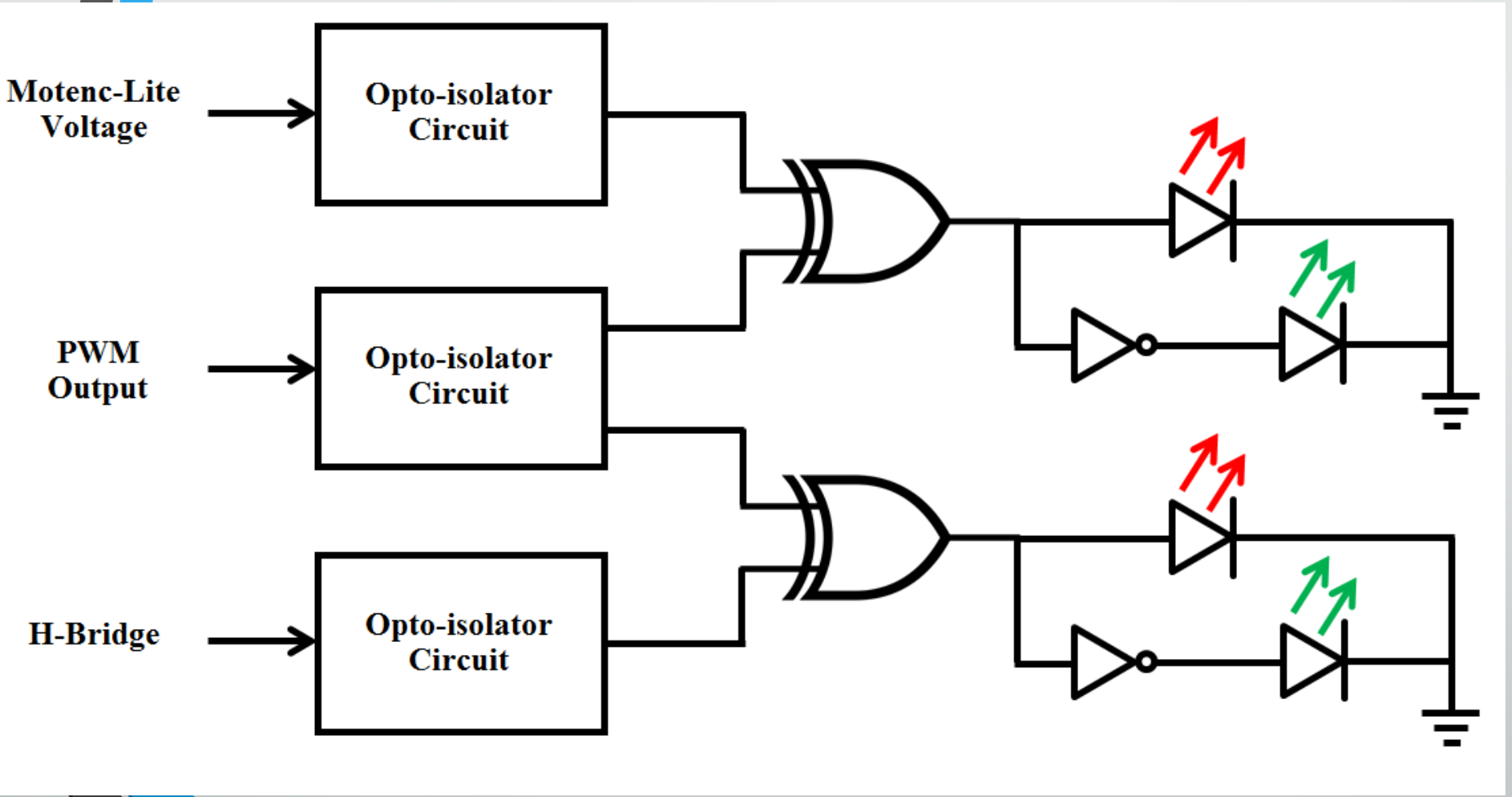
- Protect our PCBs and power supplies
- Need fans for air-flow cooling
  - H-Bridge produces lots of heat
- Chassis ground isolations



Additional Slides

Status Sub-circuit

- Electronic components fail over time
- Sub-circuit indicates which component has failed
  - Opto-isolators sense damaged components
  - Logic gates and LEDs provide visual cues
- Need to account for current transfer ratio (CTR)
  - Individually tuned RC circuit for each opto-isolator


Motenc-Lite Voltage
Opto-isolator Circuit
PWM Output
Opto-isolator Circuit
H-Bridge
Opto-isolator Circuit