POWER AND GROUNDING

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Conditions

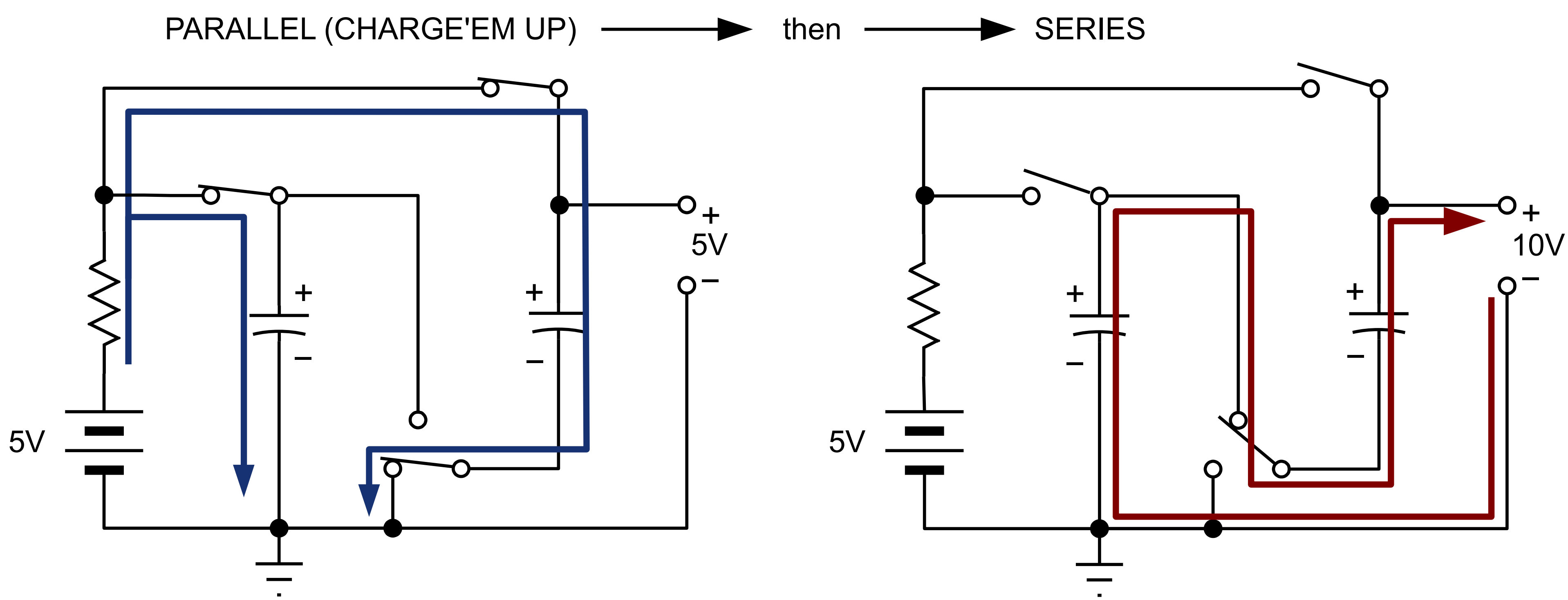
- You will have one battery (OK, 2 for 7.4V)
- But you need different voltages
  - + 5V0 for sensors
  - +3V3 for microcontroller
  - ± 5-7 V to drive motor control MOSFETS
- DC-to-DC converters can do these things

Three Main Methods

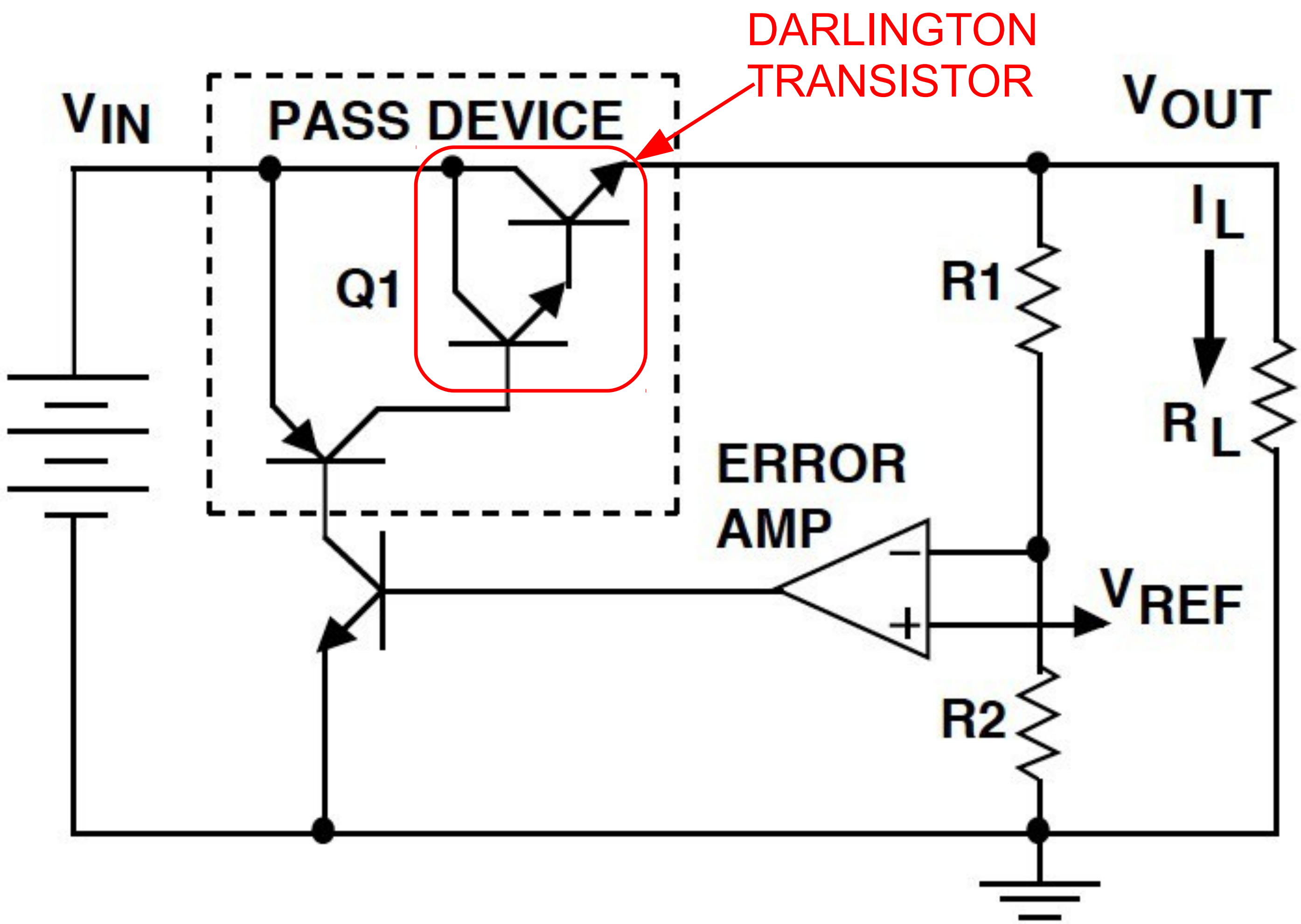
- Charge Pumps
  - High voltage, low current
  - OK for driving MOSFETs
- Linear Regulators
  - Simple
  - Low noise
  - Not efficient if big drop
  - Standard andLow Dropout (LDO)
- Switching Regulators
  - Efficient
  - High noise
  - Non-inverting & inverting
  - Boost, Buck,and Buck-Boost

Charge Pumps

- Switched Capacitors



Standard Linear Regulator



Source: Texas Instruments White Paper
http://www.ti.com/lit/an/snva020b/snva020b.pdf

LDO Linear Regulator

THE LOW-DROPOUT (LDO) REGULATOR

The Low-dropout (LDO) regulator differs from the Standard regulator in that the pass device of the LDO is made up of only a single PNP transistor (see Figure 4).

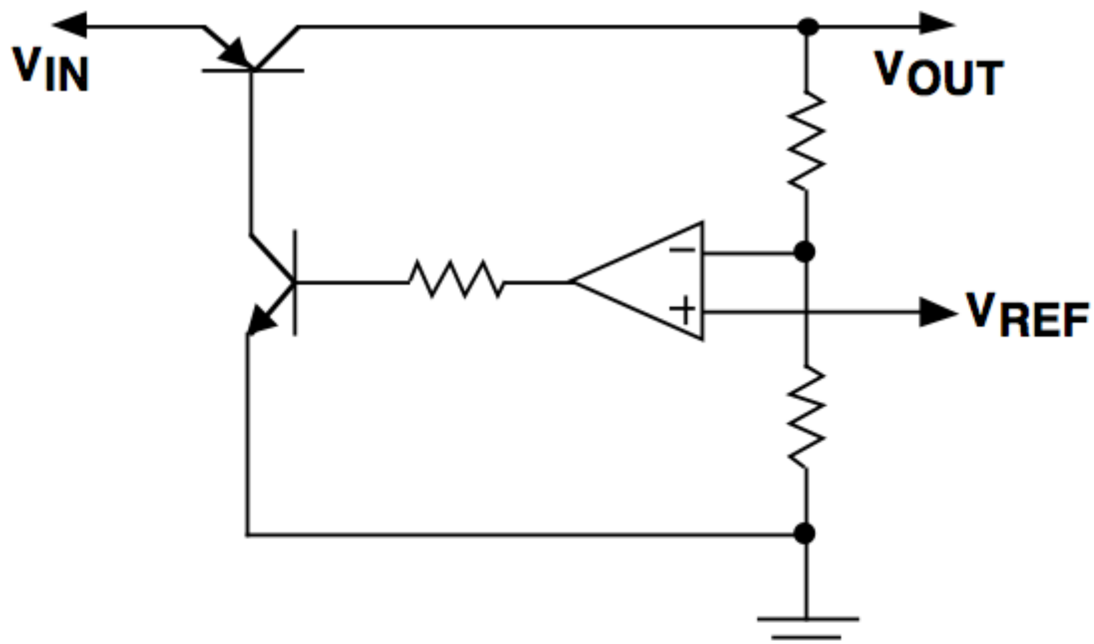


FIGURE 4. LDO REGULATOR

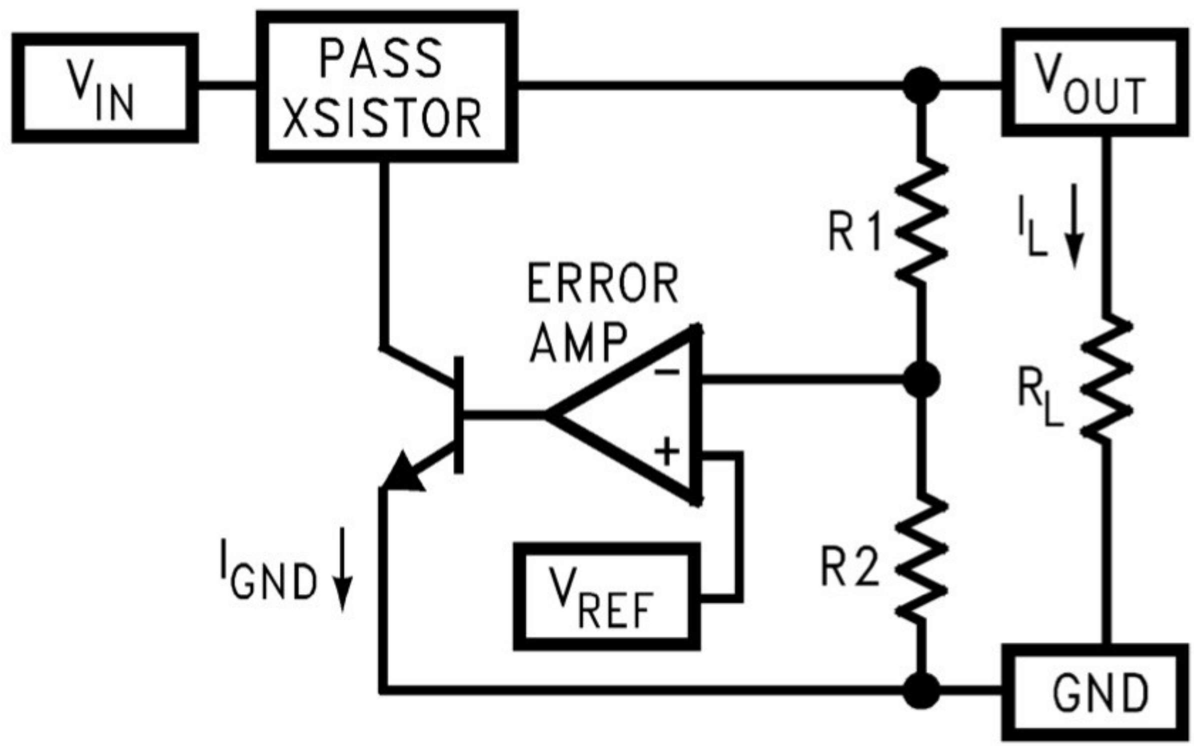
Source: Texas Instruments White Paper
http://www.ti.com/lit/an/snva020b/snva020b.pdf

Linear Regulator Operation

Negative feedback; summing point constraint holds.

$$v_n = V_{\mathrm{REF}} = V_{\mathrm{OUT}}\left(\frac{R_2}{R_1+R_2}\right)$$

$$V_{\mathrm{OUT}} = V_{\mathrm{REF}}\frac{R_1+R_2}{R_2} = V_{\mathrm{REF}}\left(1+\frac{R_1}{R_2}\right)$$



Source: Texas Instruments White Paper
http://www.ti.com/lit/an/snva020b/snva020b.pdf

LDO Stability Issues

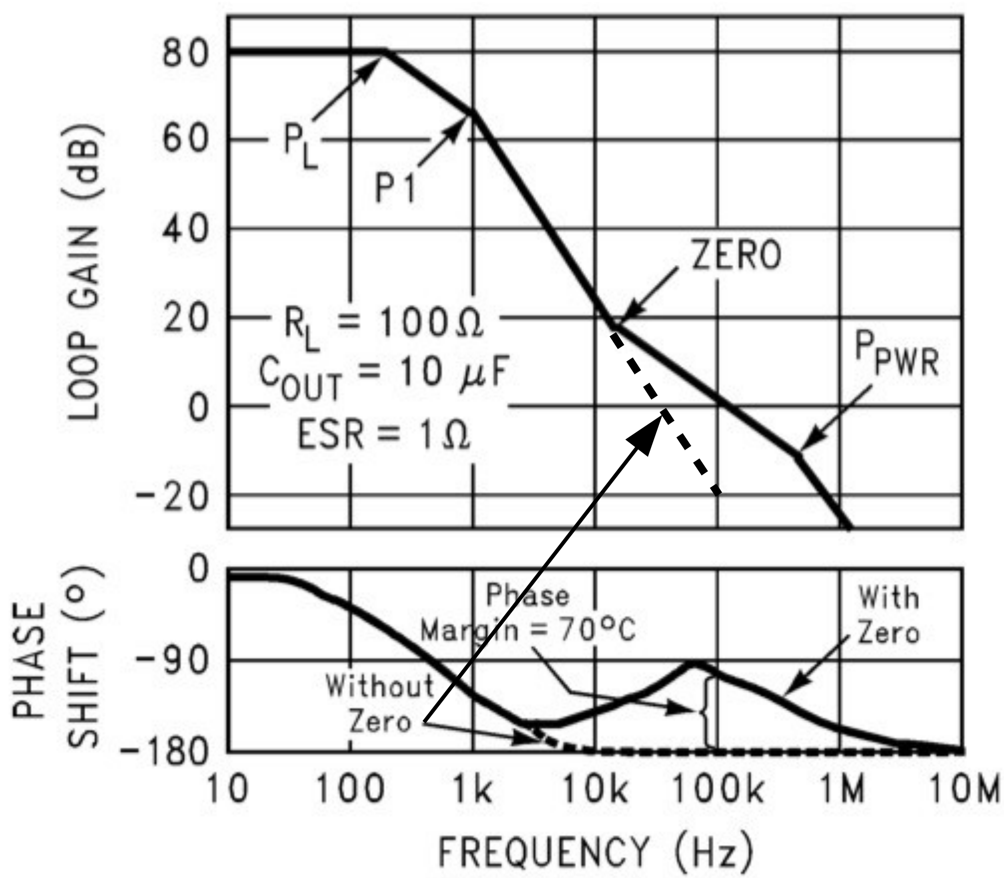


Figure 15. ESR Zero Stabilizes LDO

source: http://www.ti.com/lit/an/snva020b/snva020b.pdf

LDO Stability Issues

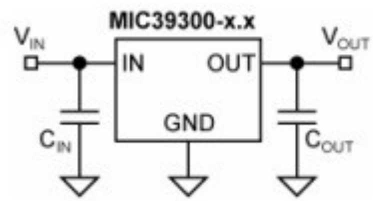


Figure 1. Capacitor Requirements

Output Capacitor

The MIC39300/1/2 requires an output capacitor to maintain stability and improve transient response. Proper capacitor selection is important to ensure proper operation. The MIC39300/1/2 output capacitor selection is dependent upon the ESR (equivalent series resistance) of the output capacitor to maintain stability. When the output capacitor is 47µF or greater, the output capacitor should have less than 1Ω of ESR. This will improve transient response as well as promote stability. Ultralow ESR capacitors, such as ceramic chip capacitors may promote instability. These very low ESR levels may cause an oscillation and/or underdamped transient response. A low-ESR solid tantalum capacitor works extremely well and provides good transient response and stability over temperature. Aluminum electrolytics can also be used, as long as the ESR of the capacitor is < 1Ω.

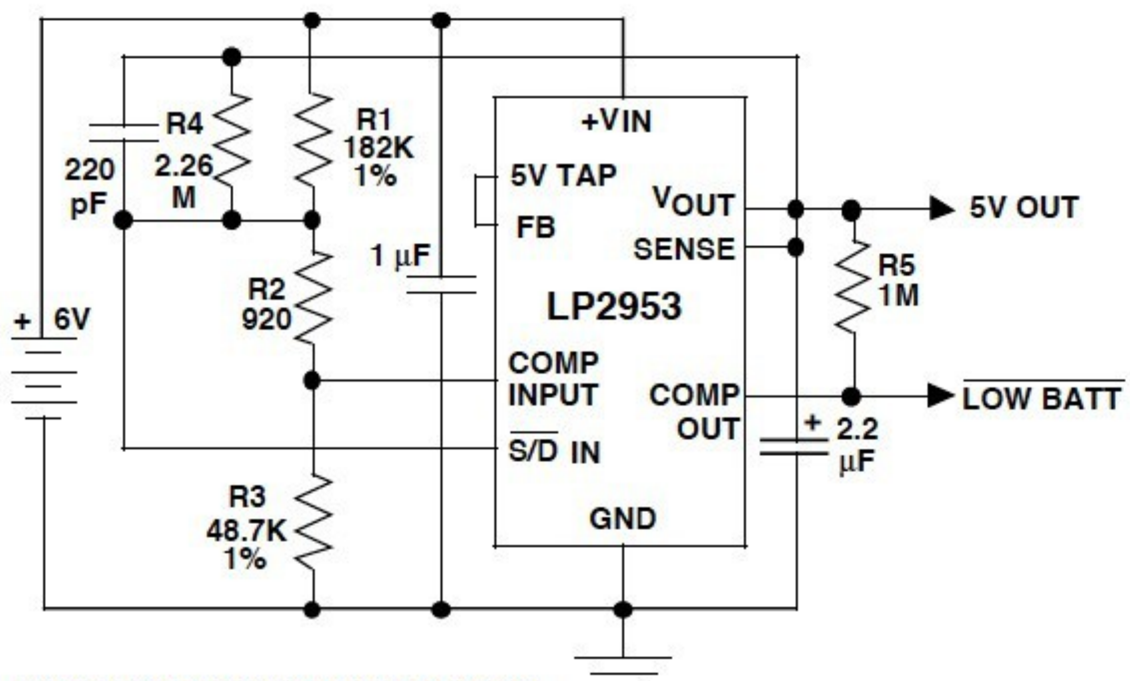
The value of the output capacitor can be increased without limit. Higher capacitance values help to improve transient response and ripple rejection and reduce output noise.

Source: Micrel MIC39000/39001/39002 Data sheet

Linear Regulator Snap On / Off

SNAP ON/SNAP OFF OUTPUT PREVENTS µP ERRORS

Microprocessors can malfunction when their supply voltage drops below 3V. Unfortunately, many of the newer microprocessors remain active (alive) down to voltages as low as 1.5V. This requires that the designer make sure that the supply voltage does not remain in the area where problems can occur for any significant period of time.



FOR COMPONENT VALUES SHOWN:
OUTPUT SNAPS ON WHEN BATTERY VOLTAGE EQUALS 5.84V
OUTPUT SNAPS OFF WHEN BATTERY VOLTAGE DROPS TO 5.44V
LOW BATTERY FLAG GOES LOW WHEN BATTERY VOLTAGE EQUALS 5.55V

Source: National Semiconductor White Paper
http://www.national.com/assets/en/appnotes/f4.pdf

Switching Regulator (Buck)

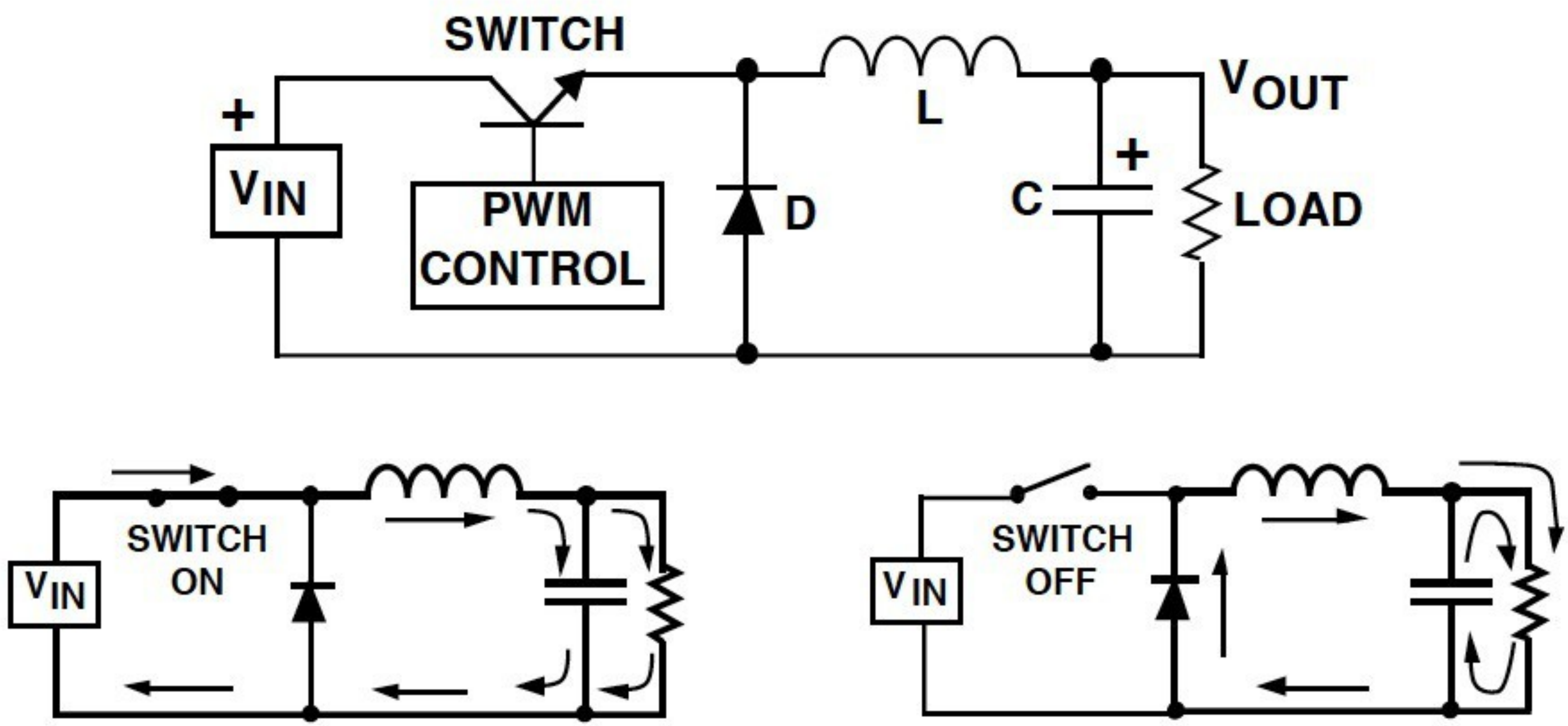


FIGURE 29. BUCK REGULATOR

Source: National Semiconductor White Paper
http://www.national.com/assets/en/appnotes/f5.pdf

Switching Regulator

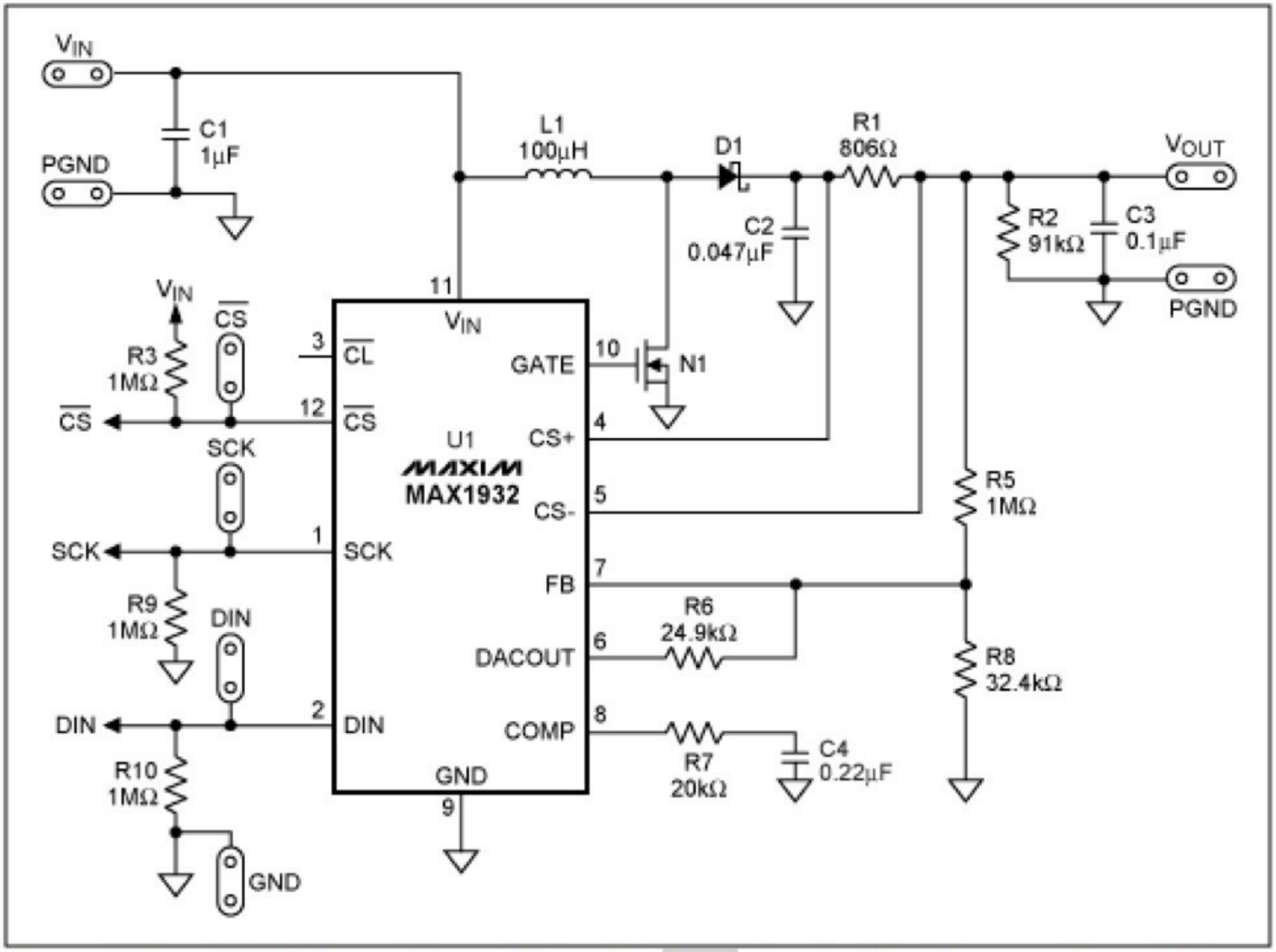


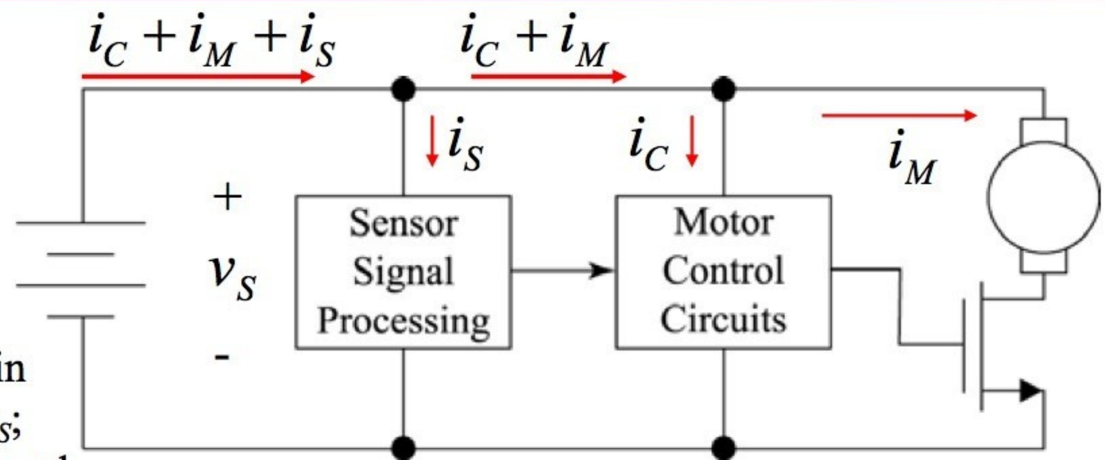
Figure 8. The MAX1932 provides an integrated boost circuit with voltage-mode control.

Source: Maxim Appnotes

Power Isolation

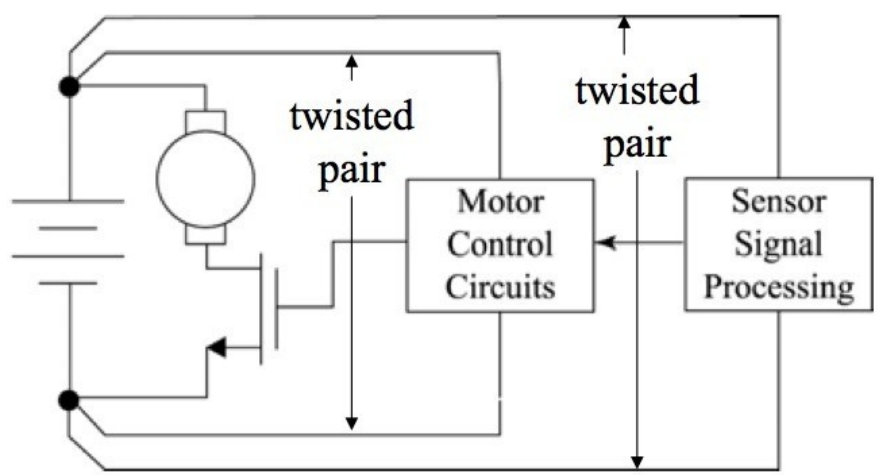
Power and Ground

BAD



(e.g., changes in i_M will affect v_S; remember that real wires have resistance!)

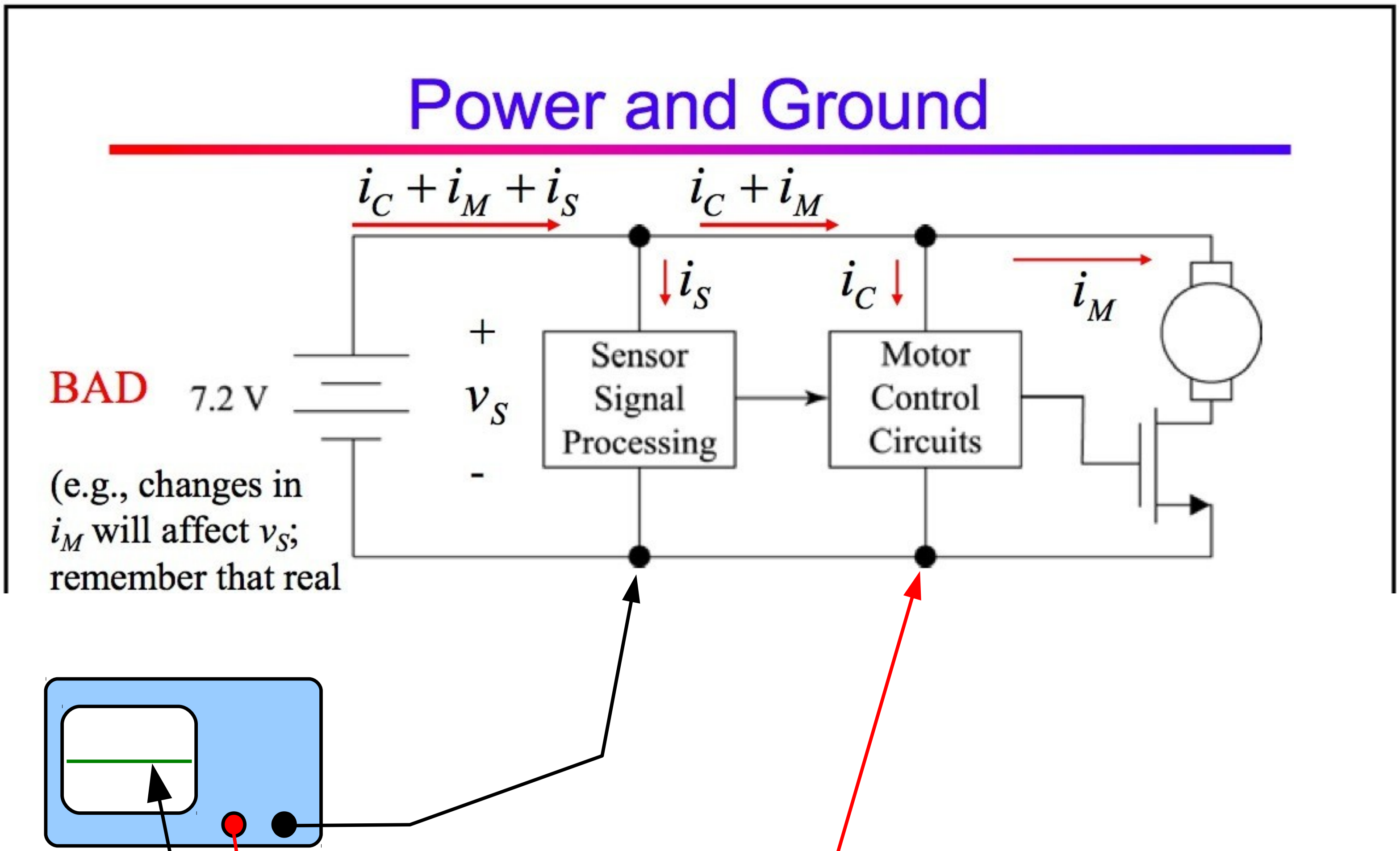
GOOD



(e.g., changes in i_M will not affect any other voltage)

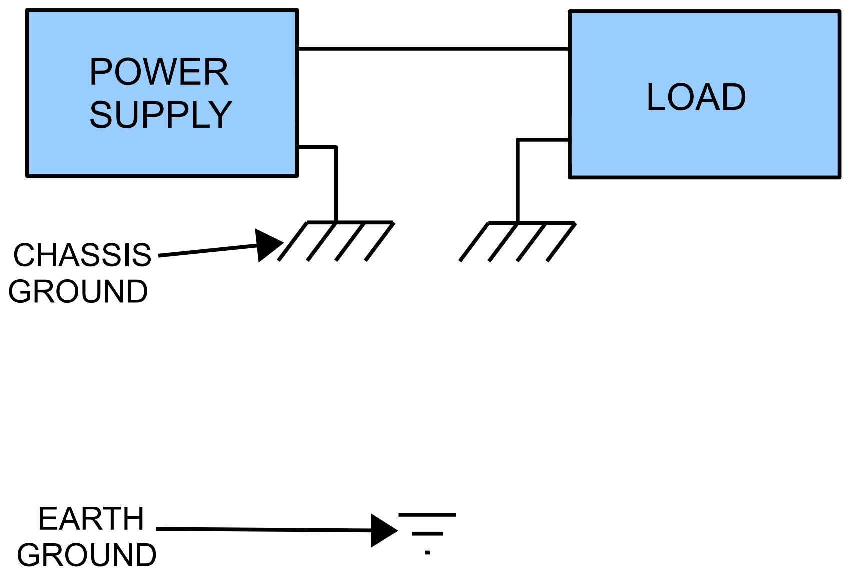
Source: Prof. Richard Spencer, UCD

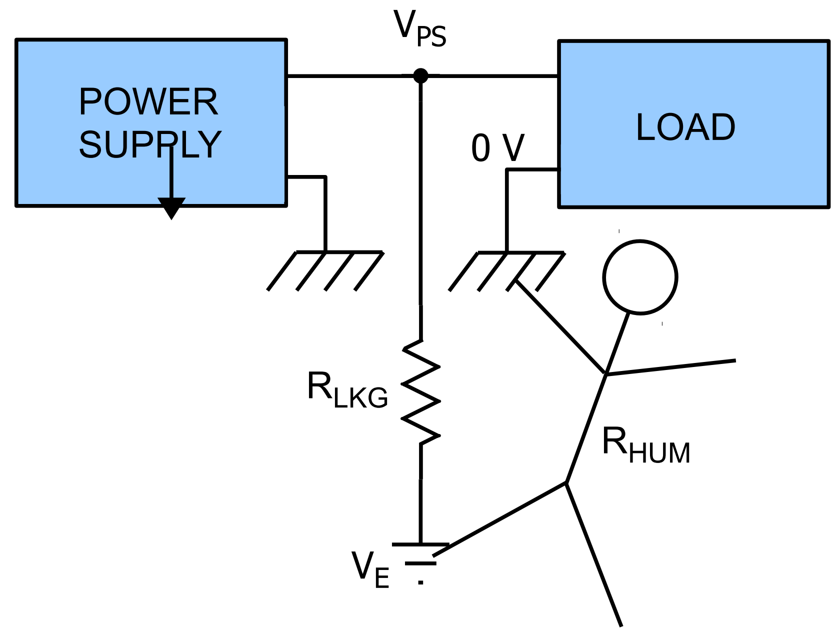
Testing Your Grounds



With the motor running, the line should be flat.

Instrumentation Grounds

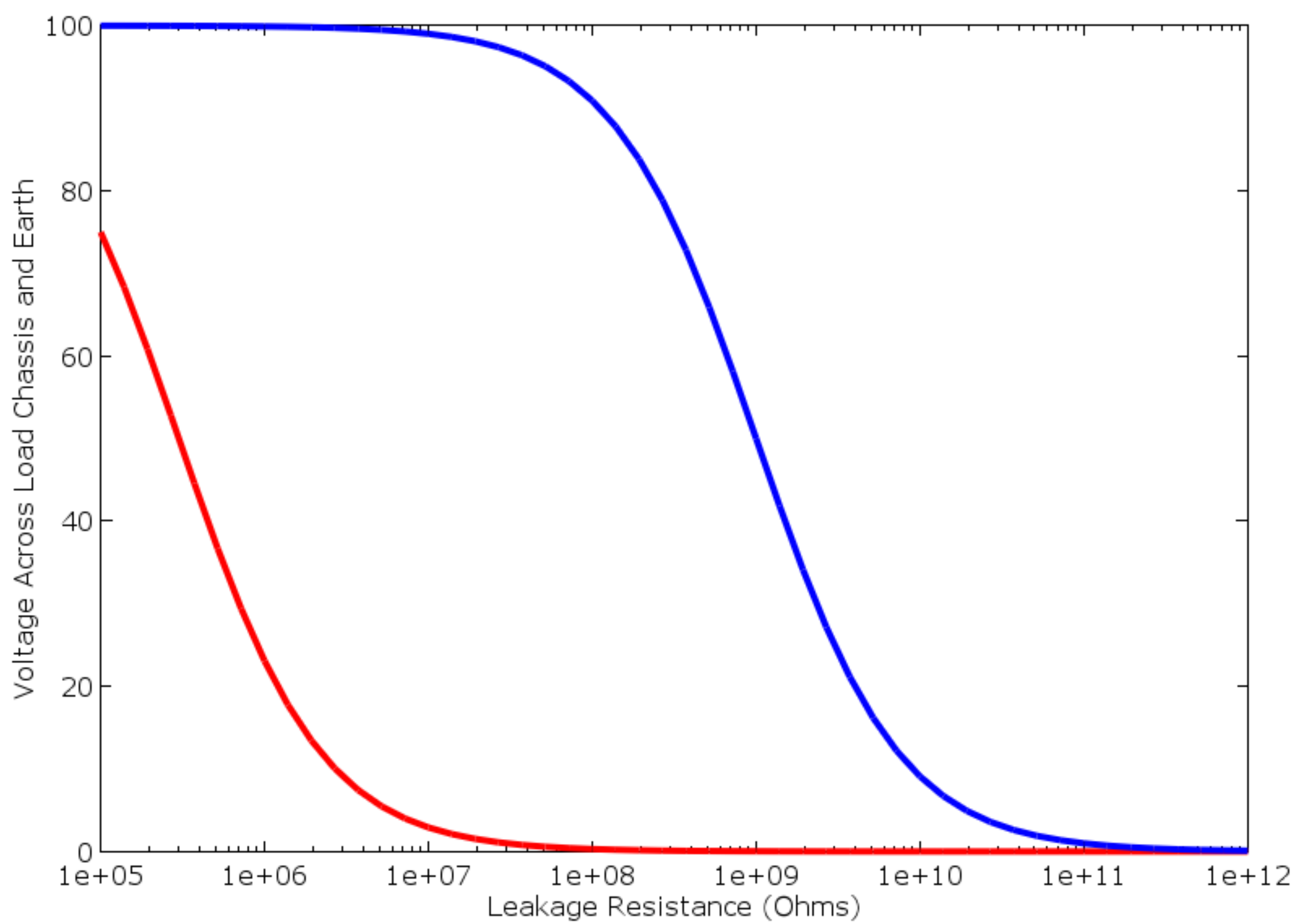




KCL at Earth Ground (V_E):

$$\frac{V_E - V_{PS}}{R_{LKG}} + \frac{V_E}{R_{HUM}} = 0$$

$$V_E = \frac{V_{PS} \cdot R_{HUM}}{R_{HUM} + R_{LKG}}$$


100
80
60
40
20
0
1e+05
1e+06
1e+07
1e+08
1e+09
1e+10
1e+11
1e+12
Voltage Across Load Chassis and Earth
Leakage Resistance (Ohms)

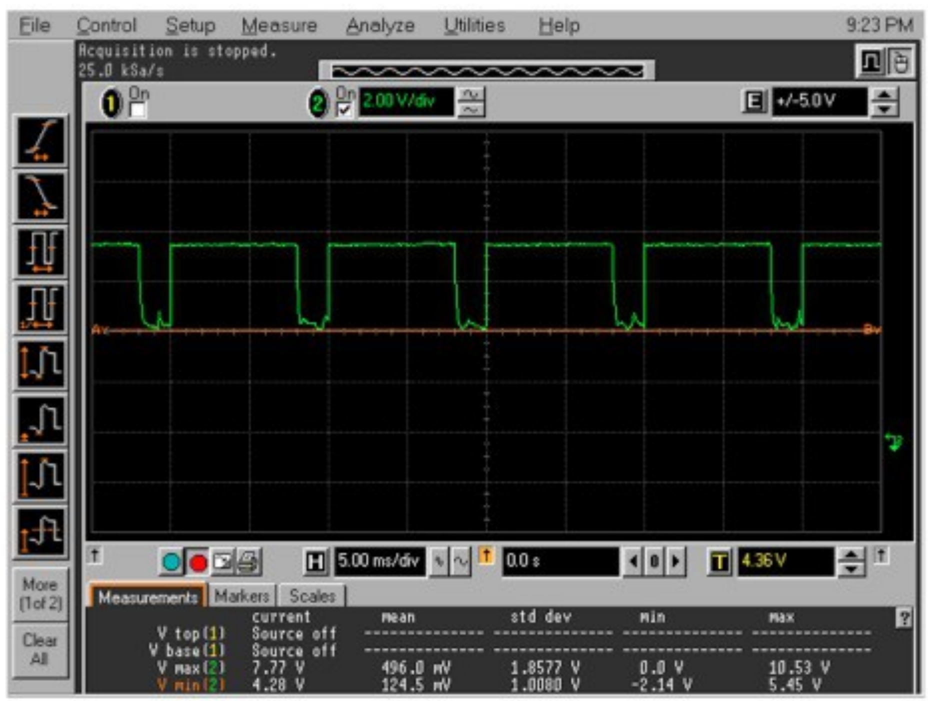
Natcar

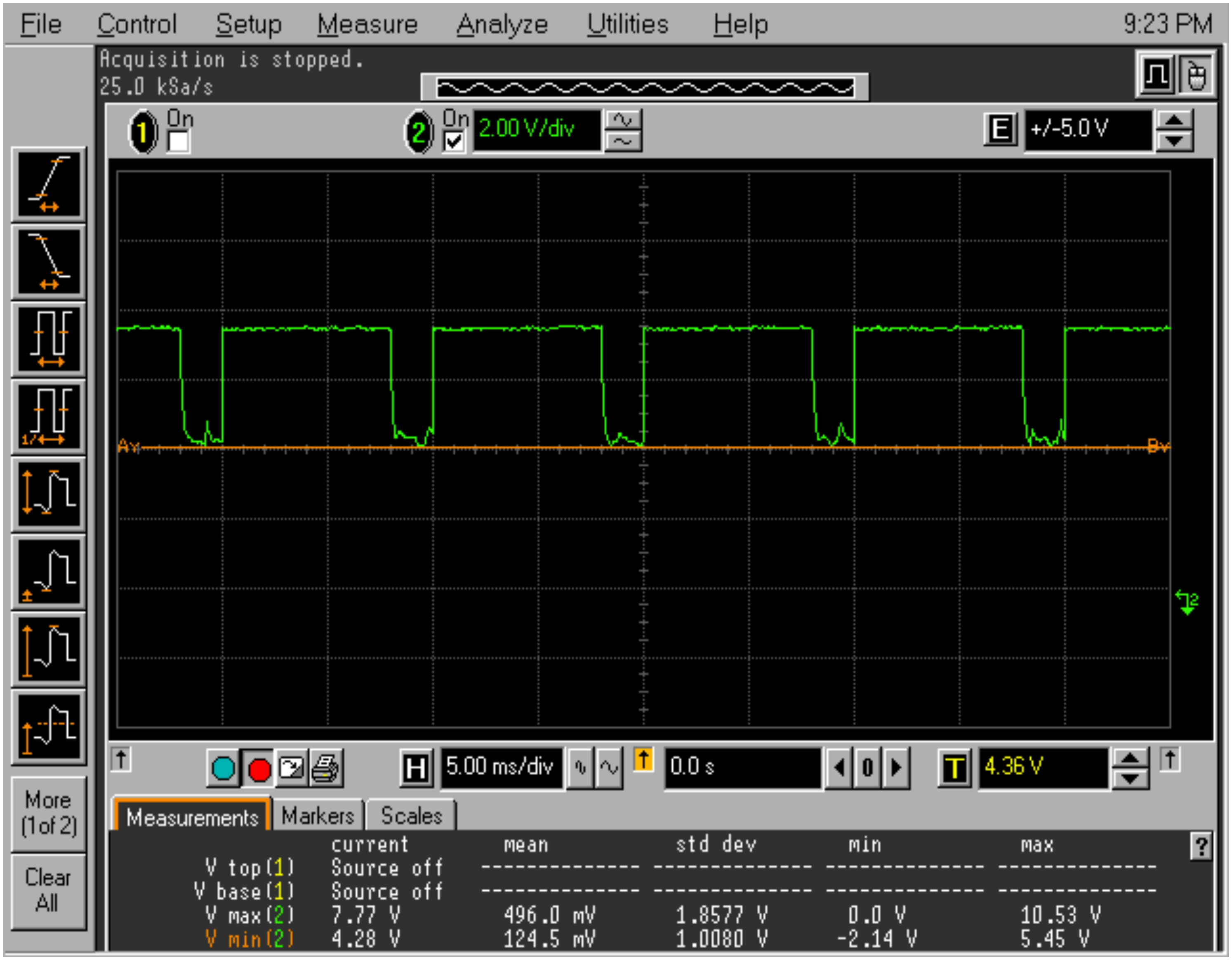
A NATCAR GROUNDING STORY

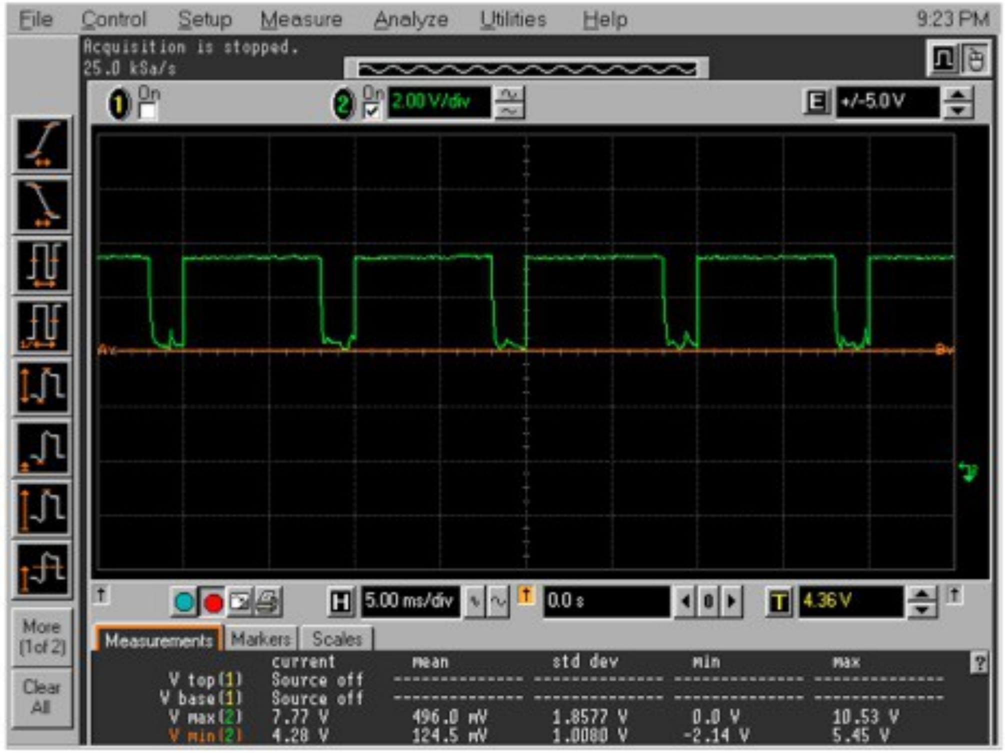
Source: “NATCAR – Team Pathfinder”; John J. Jang, Siu Ching (Connie) Kwan, Sonny T. Bui, Michael Chan, UCLA Department of Electrical Engineering, Final Report, Course EE184D, 2012-13 School Year

A. *Motor Driver*

As mentioned previously, the motor driver circuit caused more than a handful of problems to the rest of the car. In the initial testing period in the project, everything was tested on breadboards. After about 11 weeks of trying to troubleshoot all the noise issues we were seeing at varying points in the car's circuits, it was decided early on in the second quarter to finally make the move from the breadboard to a perforated board for all the circuits, and to securely solder everything. During this time, it was realized that the severely fluctuating voltages were not merely due to the motor drawing too much current, but because the ground was unstable. When two different points of the ground were probed, one near the battery and another where the AFE was, for instance, we were seeing voltage fluctuations as large as 4V, *on the same ground node!* The ground's voltage was building up, which explained the near 4V fluctuations in voltage across the battery itself, as shown in the photograph below.

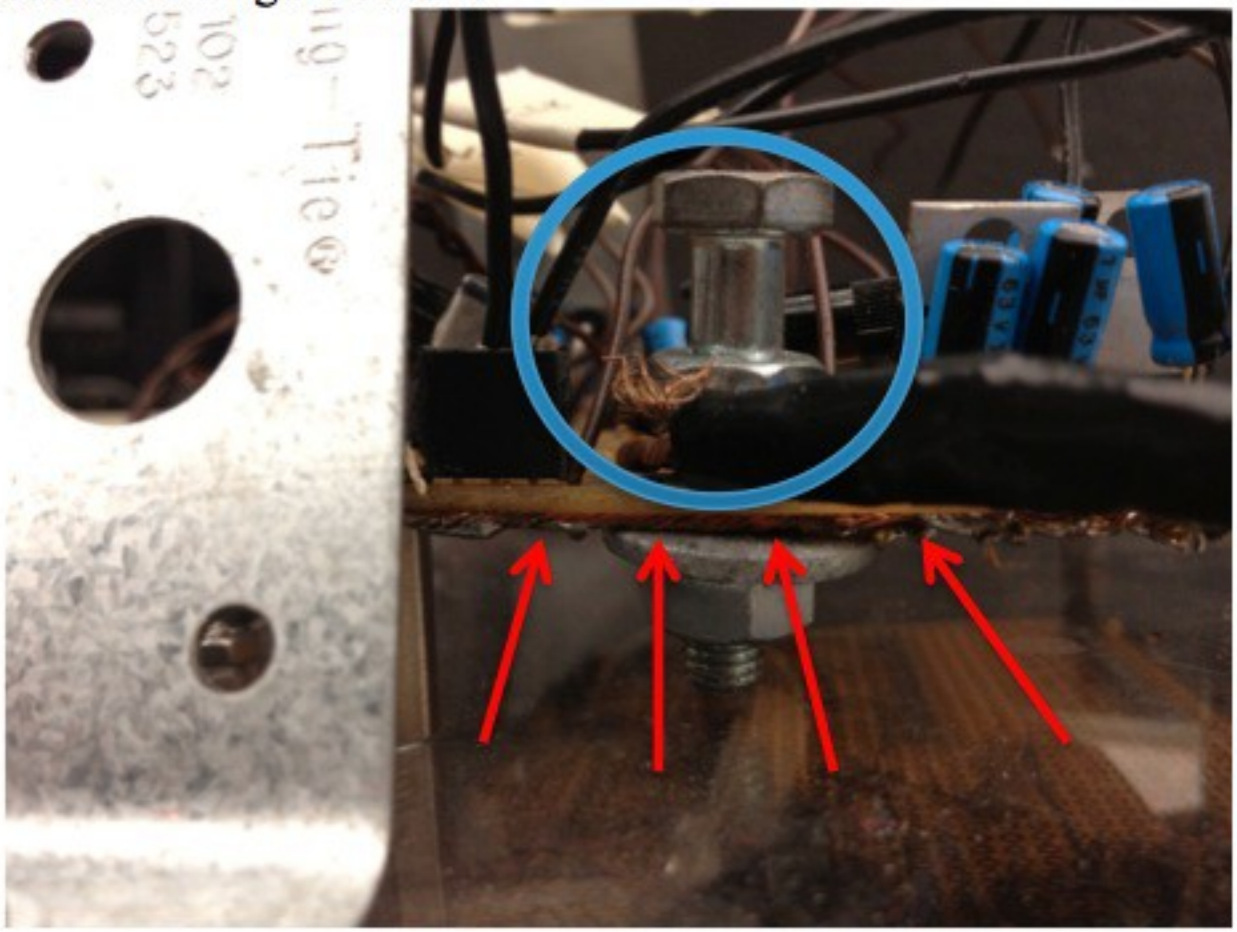


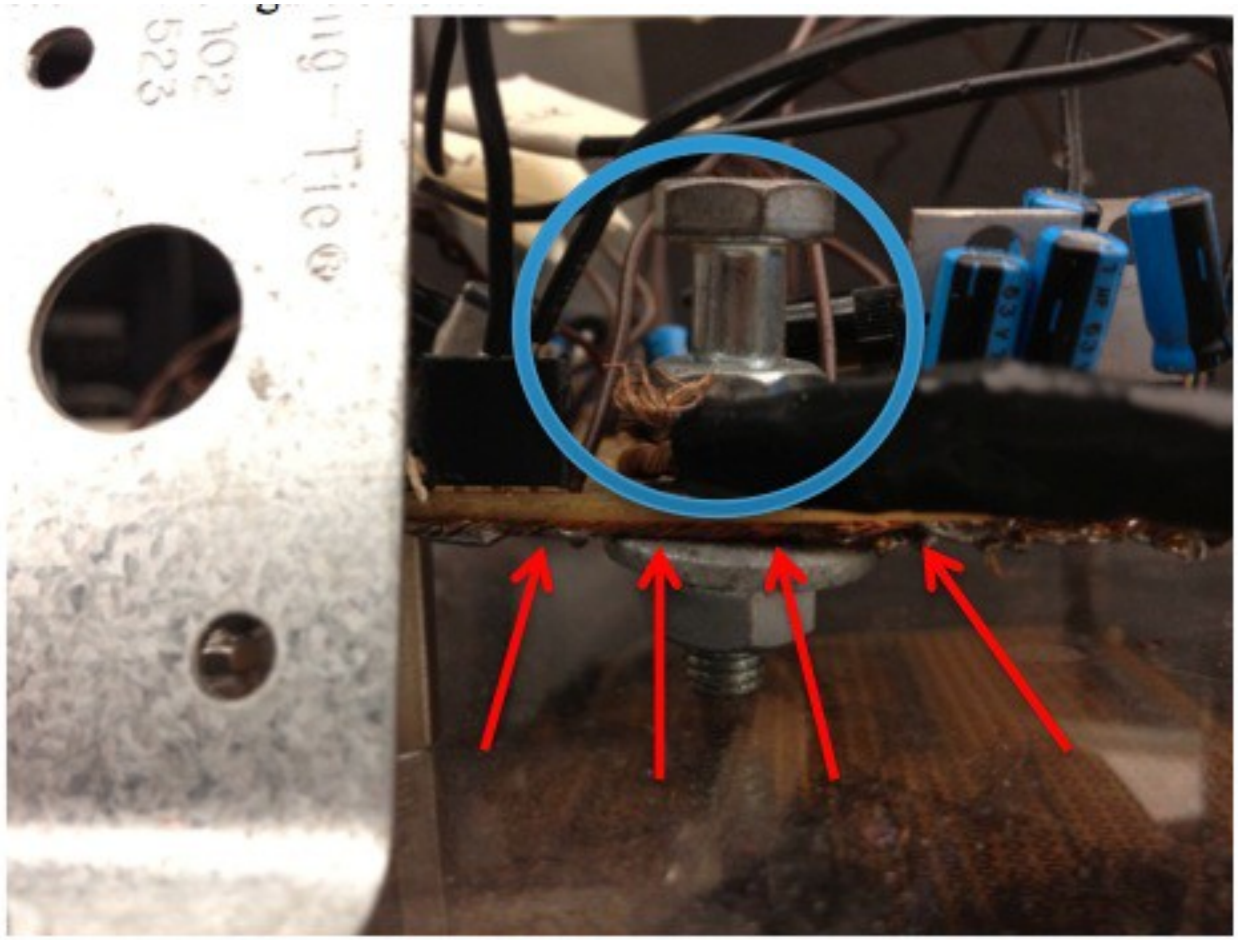

File Control Setup Measure Analyze Utilities Help
9:23 PM
Acquisition is stopped.
25.0 kSa/s
On
On
2.00 V/div
E
+/-5.0 V
H
5.00 ms/div
0.0 s
T
4.36 V
More (1of 2)
Clear All
Measurements
Markers
Scales
current mean std dev min max
V top(1) Source off
V base(1) Source off
V max(2) 7.77 V 496.0 mV 1.8577 V 0.0 V 10.53 V
V min(2) 4.28 V 124.5 mV 1.0080 V -2.14 V 5.45 V



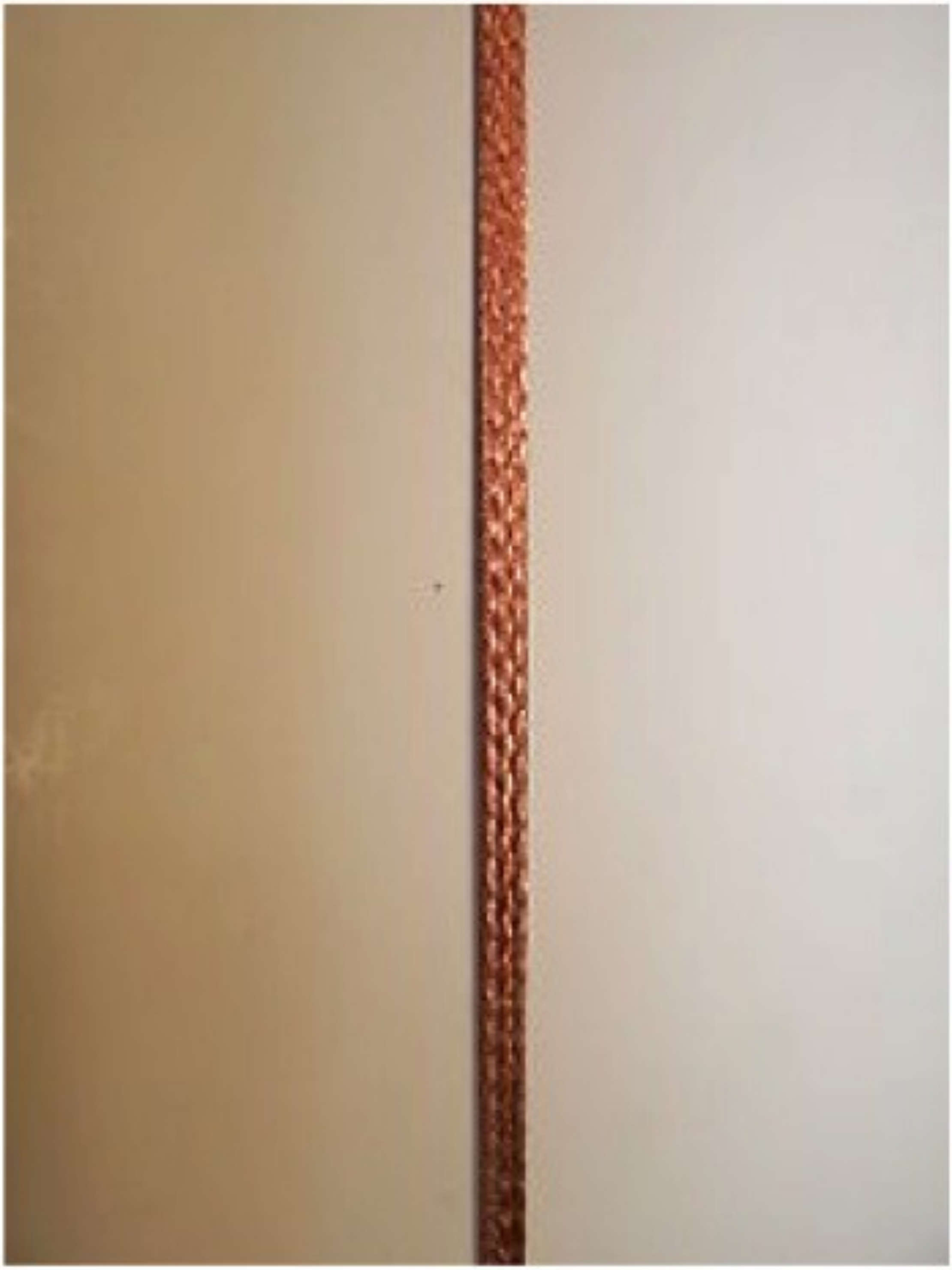
As much as the curve in the figure above seems to be a PWM signal, it is *not*. This was the voltage across the battery as the PWM triggered the BJT amplifier on and off, thereby turning the MOSFETs and the motor on and off. Each -4V dip indicates an ON period of the motor. With the ground this unstable, it was clear and obvious that nothing would work when the motor was spinning. It was during this time that shorter, thick wires replaced the thin ones that were used with the breadboards.

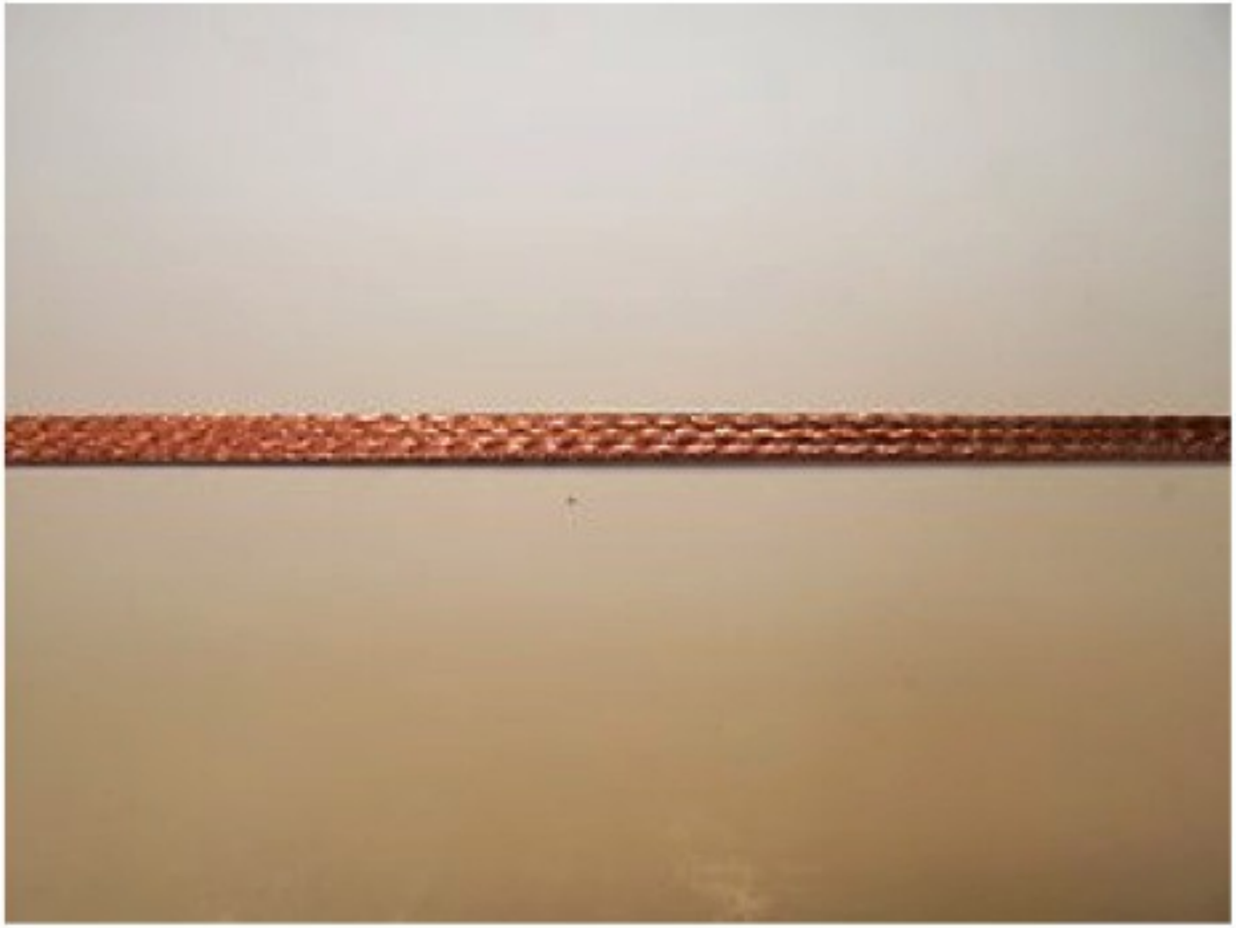
The idea behind using thick, short wires with multiple strands intertwined together was to accommodate the skin effect. Because everything in NATCAR operates at high frequencies, electrons, rather than moving in an evenly distributed manner through the wire, they begin to move on the surface of the wire. In an ideal situation, the ground would be an infinite plane of conductive material. However, such environment could not be built on top of the limited space on the NATCAR's body. Thus, thicker wires composed of multiple thinner wires were used to dramatically increase the surface area on which electrons could travel in this high frequency situation. A "ground bus" was tapped from the negative terminal of the battery to each of the perforated boards, and all grounds were connected to the bus. as can be seen in the figure below.





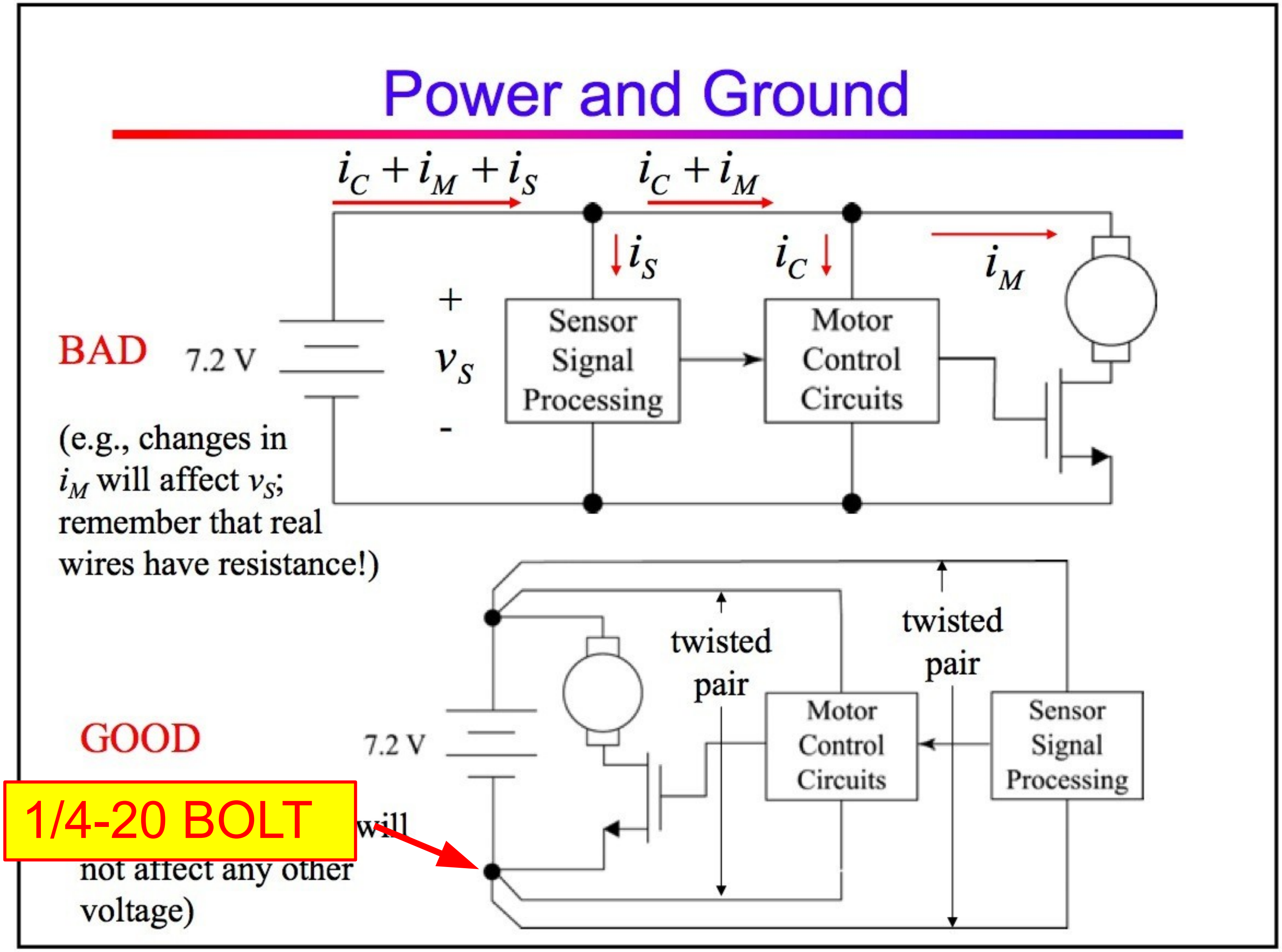
Even after a ground bus was installed, the ground was still somewhat fluctuating. That is when dramatic measures were taken, and six thick wire strands were stripped, then braided into *two* of what you see in the figure below, and connected to the ground bus by a large, steel bolt and nut, as circled blue in the above figure.





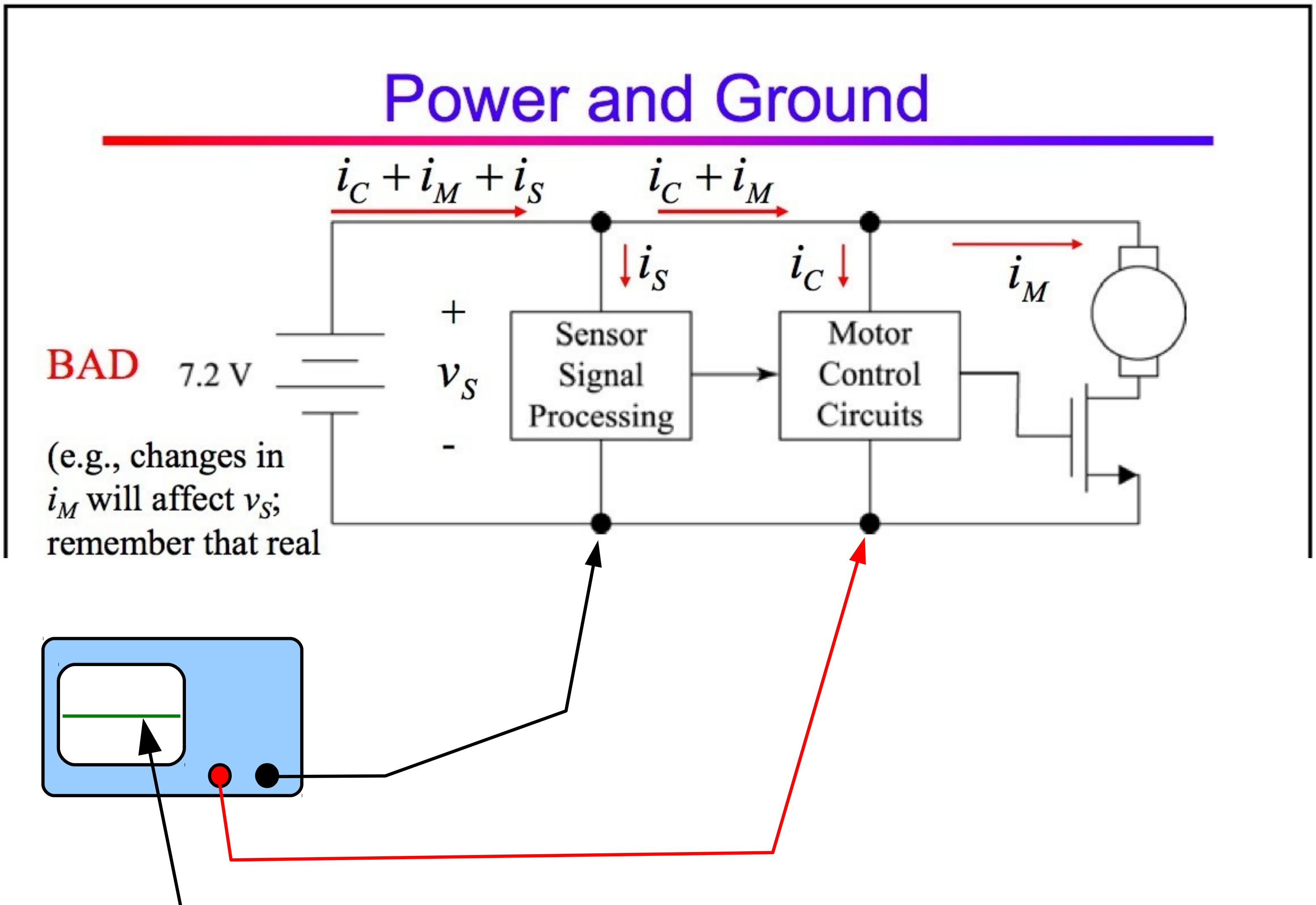
Performing the abovementioned immediately fixed all our grounding issues. We were not observing a maximum of 40mV fluctuations all across the car's circuits with or without the motor running. Also, the output of the regulators that were powering the OpAmps, the servo, and the mbed were extremely stable, never falling below 4.8V.

Power Isolation



Source: Prof. Richard Spencer, UCD

Testing Your Grounds



With the motor running, the line should be flat.

Ucla BRUINS

Switching Inverting Regulator

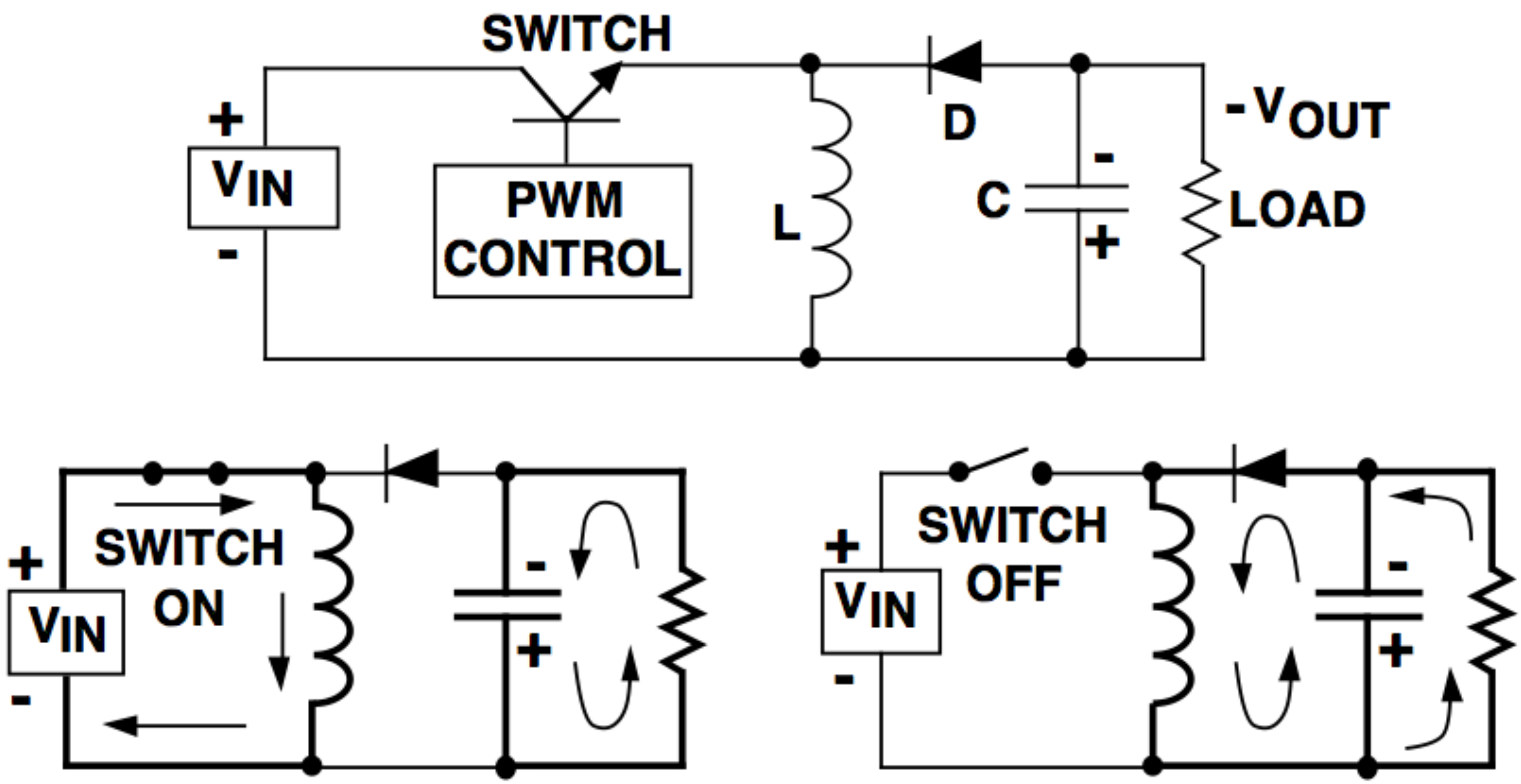
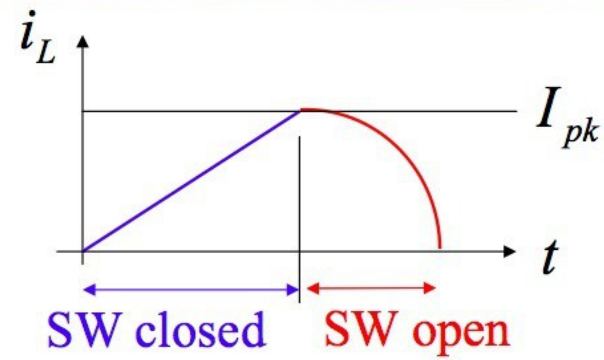


FIGURE 32. BUCK-BOOST (INVERTING) REGULATOR

Source: National Semiconductor White Paper
http://www.national.com/assets/en/appnotes/f5.pdf

Inverting Switching Regulator

Inverting Switching Regulator



SW closed:

i_L builds up; $V_I = L\dfrac{di_L}{dt}$

D is off ($V_I > V_O$).

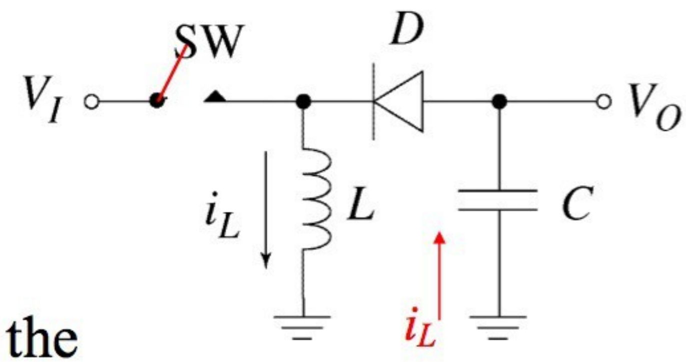
Open SW when $i_L = I_{pk}$

SW open:

i_L charges C, D is on.

D stops current in LC tank from reversing.

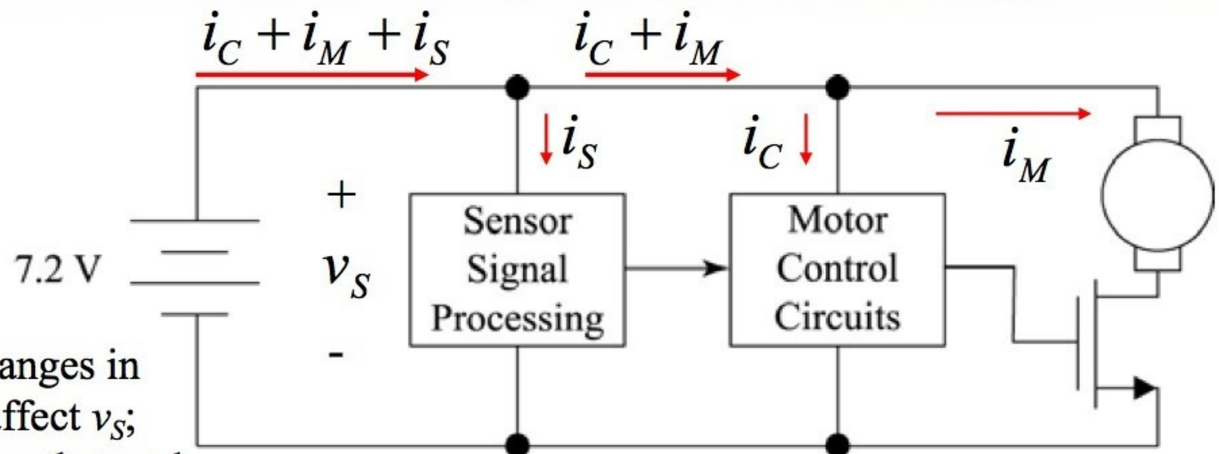
Feedback is used to control the switch and stop charging when the desired output voltage is reached.



Source: Prof. Richard Spencer, UCD

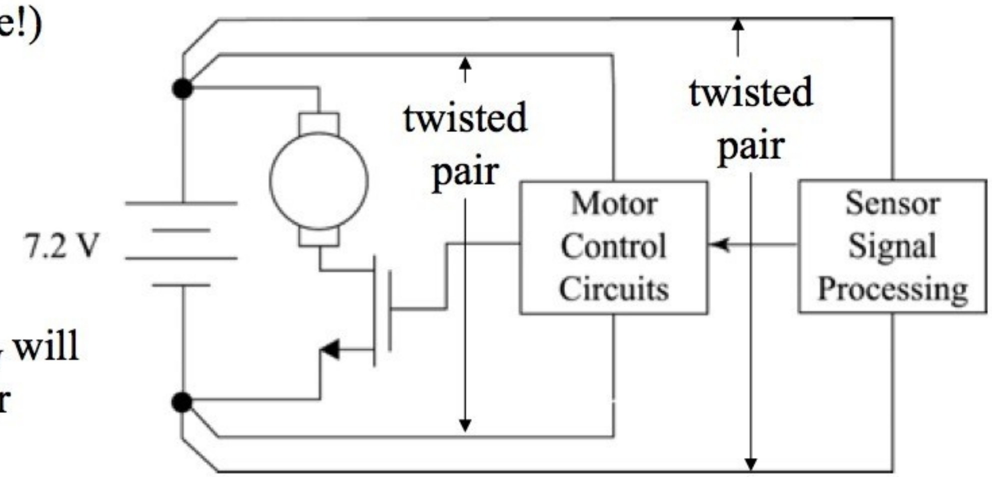
Power and Ground

BAD



(e.g., changes in i_M will affect v_S; remember that real wires have resistance!)

GOOD



(e.g., changes in i_M will not affect any other voltage)