Optional MECH 3140 Lecture: Driving Motors and Op-Amps

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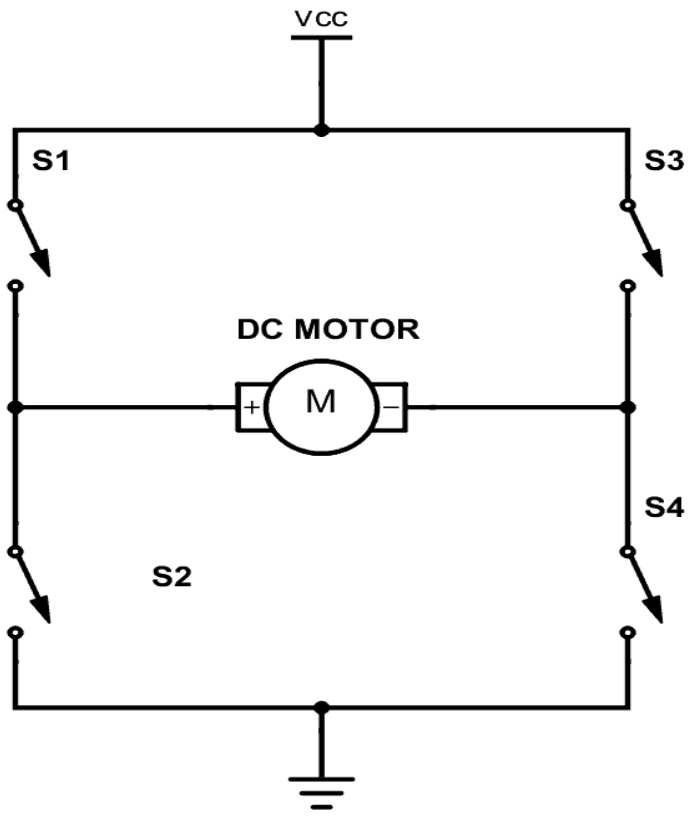
How to supply a negative voltage?

- Turns out that motors must be able to be driven in reverse
  - This is done by supplying a “negative” voltage
  - In reality this is done by reversing the polarity of the terminals across the motor
  - In control systems we can’t do this manually
    - Controller needs to be able to supply positive and negative voltages to the motor (i.e. turn the motor in either direction given a single supply
  - This is done using what is called an H-bridge

H-bridges

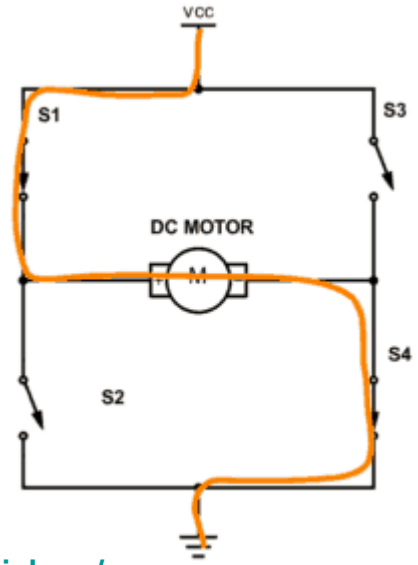
- An H-bridge allows for automatically being able to swap the polarity across the motor
  - It gets its name since it looks like an H
  - The direction of the motor is set using the 4 “switches” (S1,S2,S3,S4)



https://www.build-electronic-circuits.com/h-bridge/

H-Bridges

- To run “positive” voltage, close switch S1 and S4 (and open S2 and S3)



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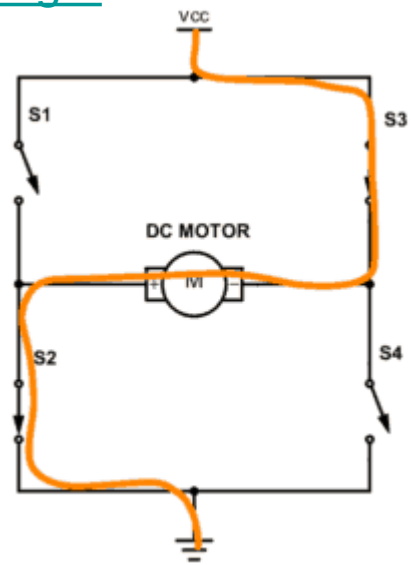
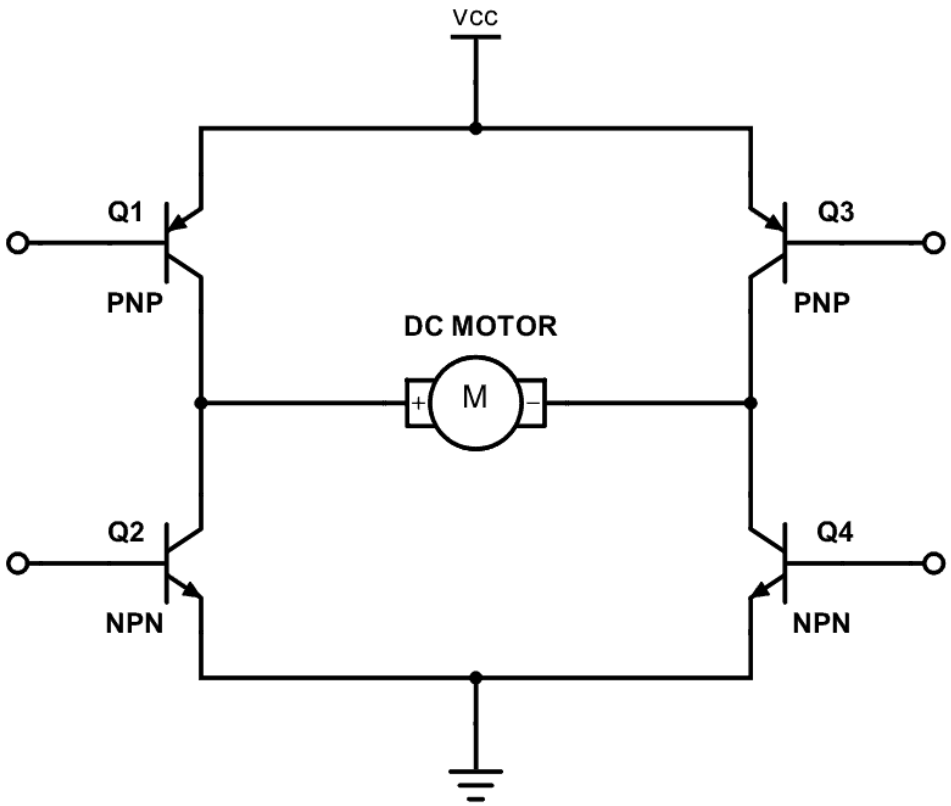
- To run “negative” voltage close switch S2 and S3 (and open S1 and S4)



H-Bridges

- The “switches” are controlled by transistors
  - Transistors are the EE version of valves



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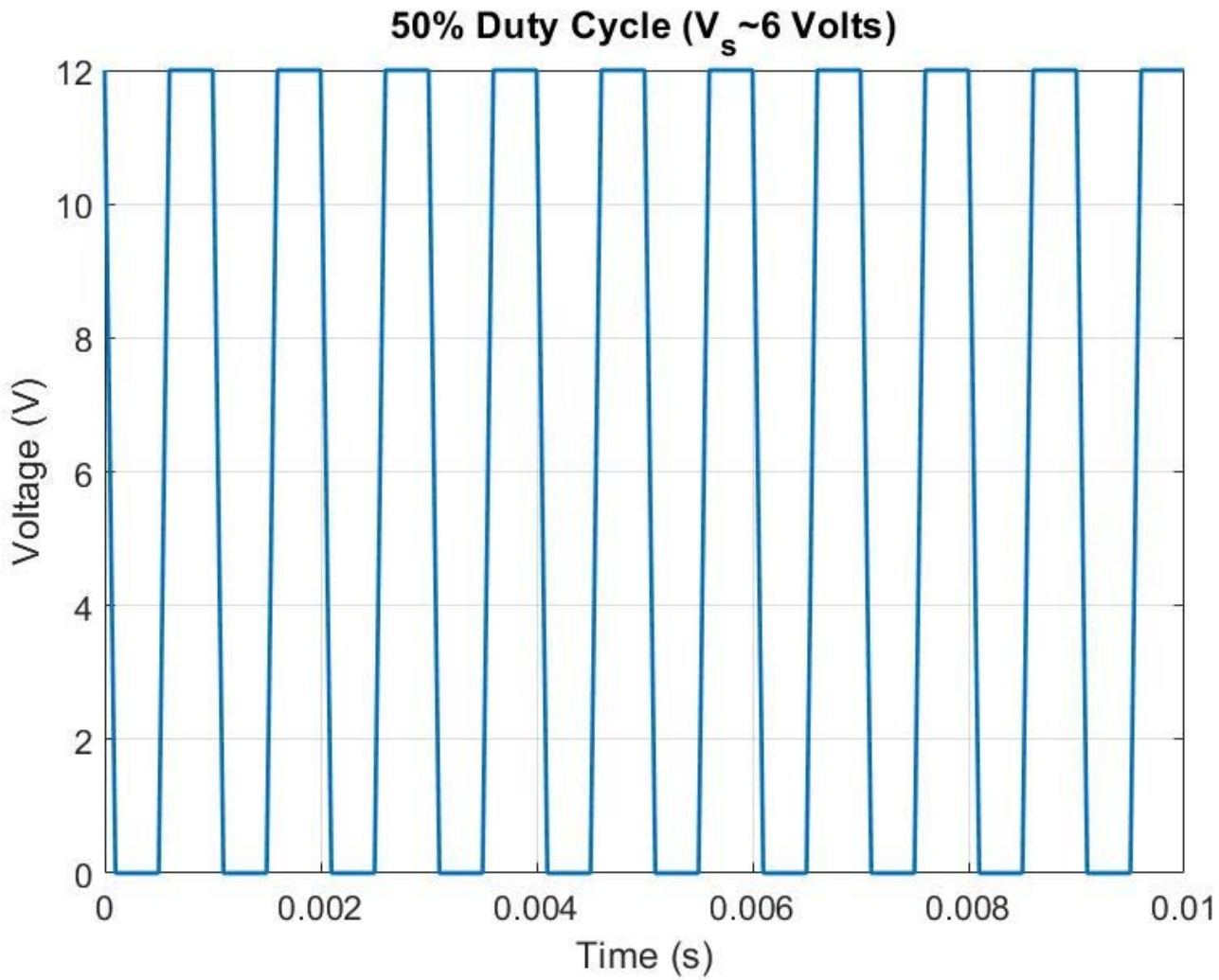
How to Set Motor Voltage?

- If you have a 12 volt supply, how do you provide 6 volts?
  - You don't use a voltage divider (i.e. two resistors)
    - This is wasting energy
    - It's the mechanical equivalent of controlling your cars speed by using full throttle and partial brakes

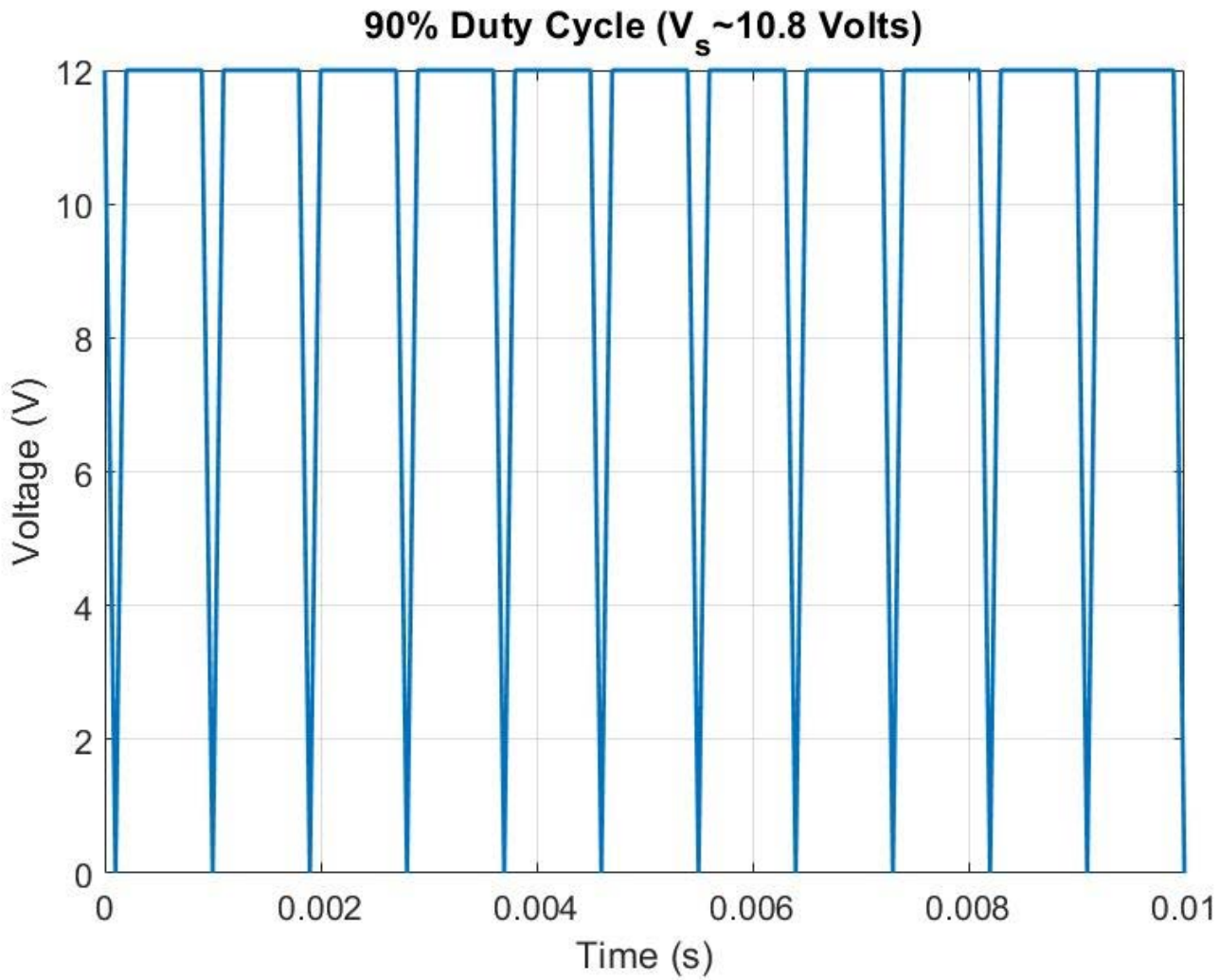
How to Control Motor Voltage?

- Provide the motor with a 12 volts supply
- Then turn the motor on for part of the time and off for part of the time
  - So you send 12 volts for part of the time and 0 volts part of the time
  - This is called Pulse Width Modulation (PWM)
  - Why doesn't the motor speed up and slow down?
    - Think frequency response!

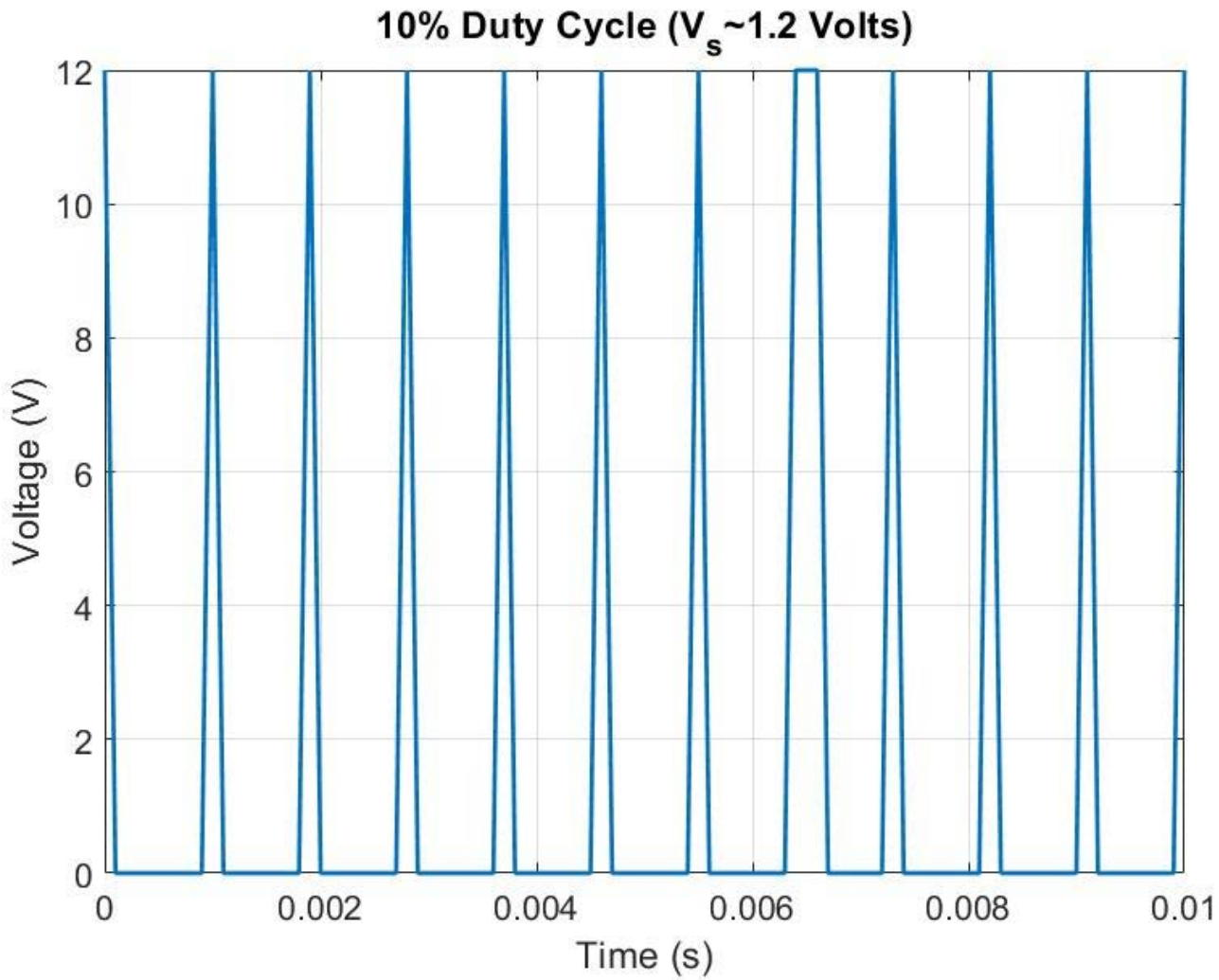
Motor V_s=6 Volts



Motor V_s=10.8 Volts



Motor V_s=1.2 Volts



How to Set Motor Voltage?

- PWM actually works with the H-bridge
  - Turn on and off the PNP transistors with the PWM signal
    - 12 volts supply is always connected
    - PWM signal dictates the effective percentage of the voltage to the motor
    - Direction is dictated by which PNP transistors you PWM on and off.
  - Most motor driver h-bridges actually have a supply line, ground, the two motor terminal connections, 1 direction line/bit, 1 PWM line
    - Such as the LMD18200 from Texas Instruments

LMD18200

AN-954

Key Features (Continued)

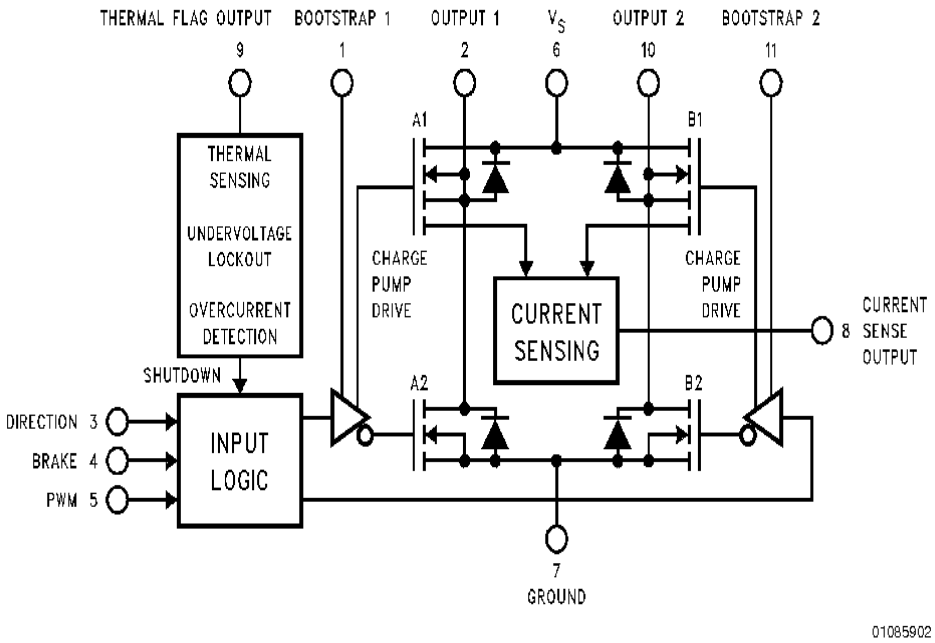
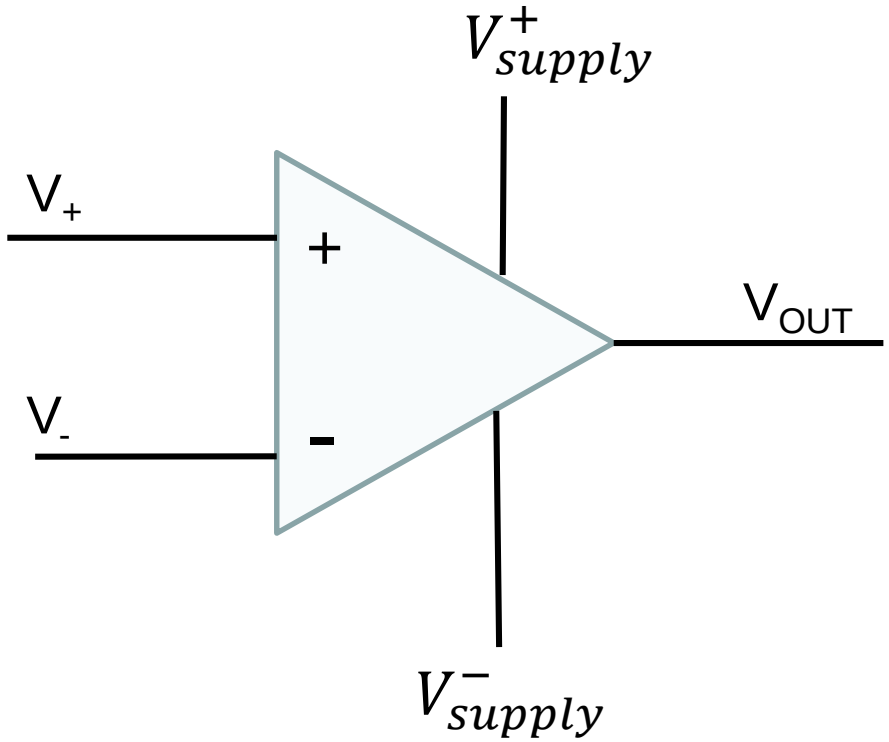


FIGURE 2. Block Diagram of the LMD18200

Operational Amplifiers (Op-Amps)

- Op-amps are extremely useful for practical applications related to mechanical systems



Op-Amp Golden Rules

- Op-Amps operate under 2 Golden Rules

  1) $I_+ = I_- = 0$ & 2) $V_+ = V_-$

  – These dictate the operation/model/equation for the op-amp set up

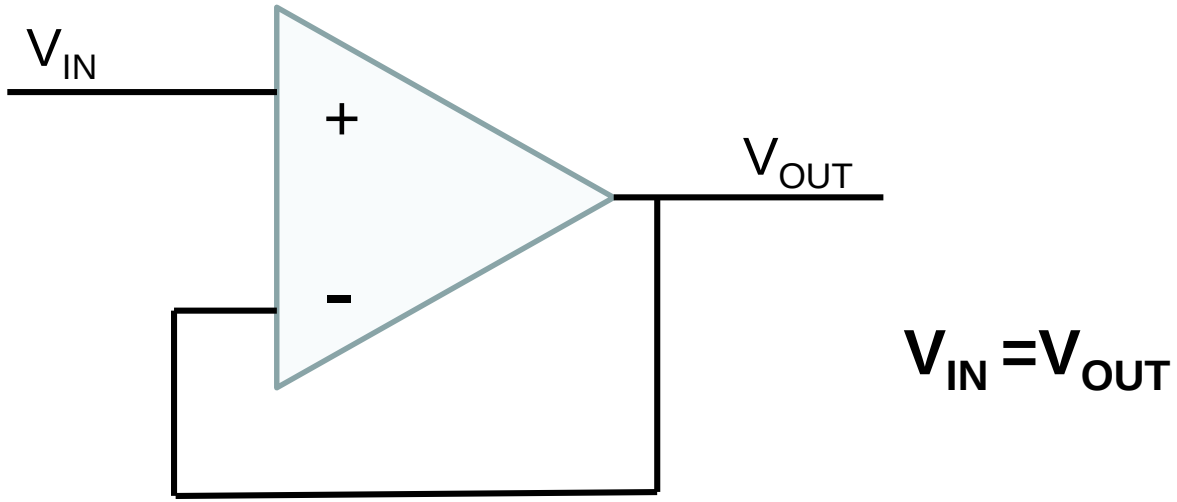
- A third principle (but not a golden rule):

$$V_{supply}^{+} < V_{out} < V_{supply}^{-}$$

- These are idealized principles
  – An op-amp specification sheet will give how close to these the actual op-amp gets
  – The closer the op-amp gets to these idealize principles, the more expensive the op-amp

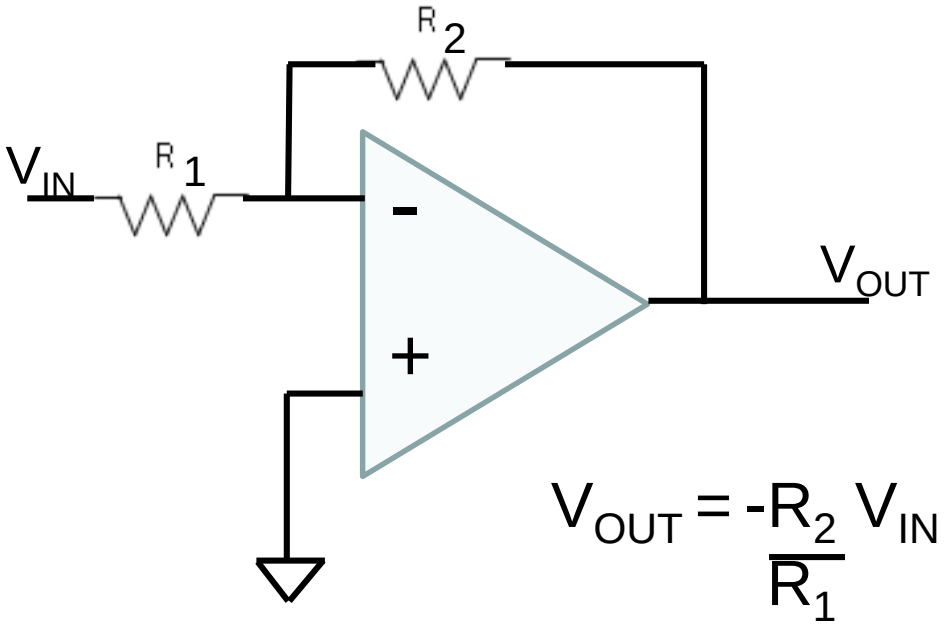
Buffer/Follower Configuration

- What would be the point of this op-amp configuration
  - Isolates a sensor measurement
    - Since the Op-Amp doesn't draw any current (i.e. one of the golden rules)



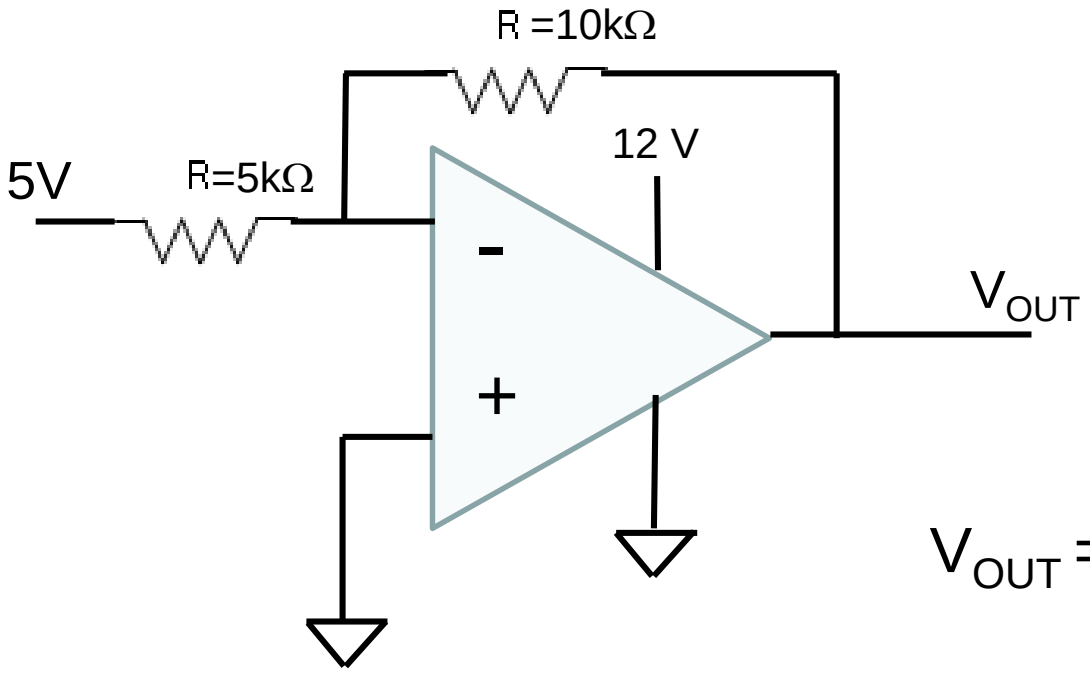
Inverse Amplifier Configuration

- What would be the point of this op-amp configuration
  - Amplify a signal
    - Utilize the full range of a data acquisition system
    - Scale the sensor measurement to full range



Inverse Amplifier Configuration

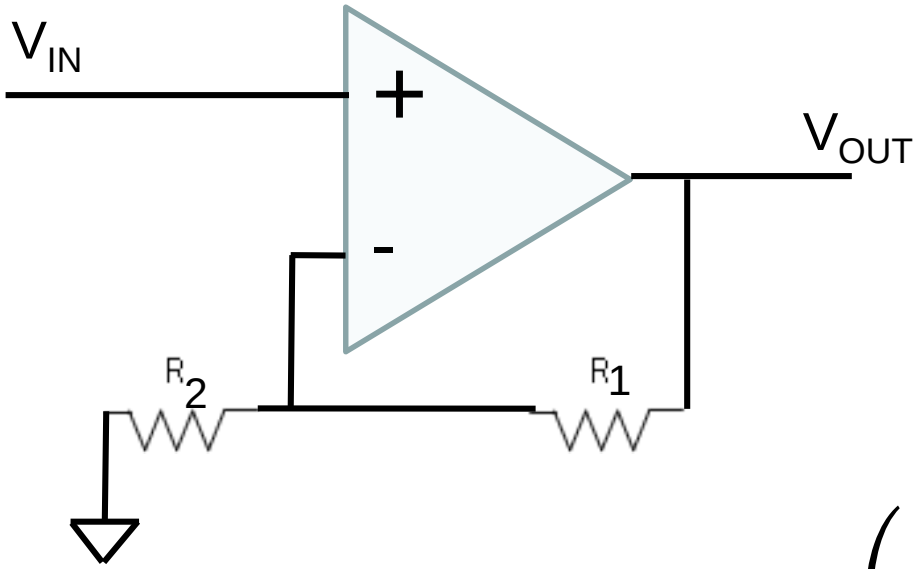
- What will the output of this Op-amp be?



$$V_{OUT} = \frac{-10}{5} V_{IN}$$

Non-Inverting Amplifier Configuration

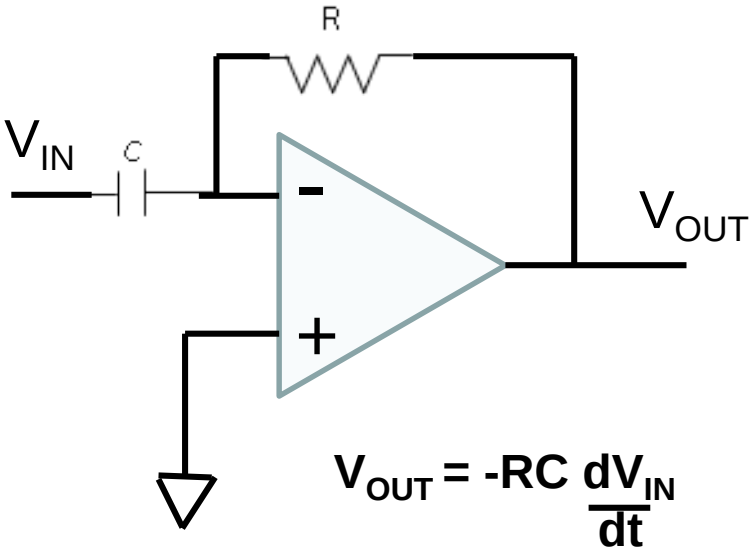
- Can also set up the amplifier in a “non-inverting” configuration to amplify a signal



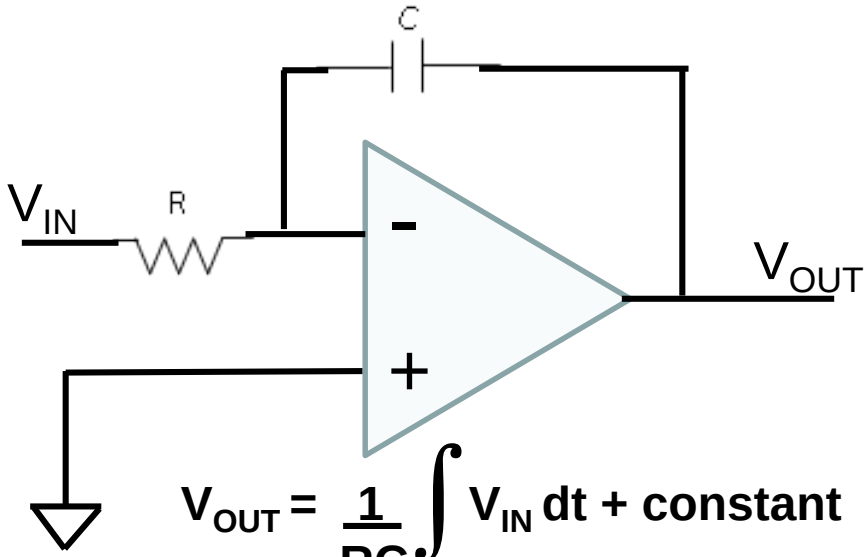
$$V_{out} = \left(1 + \frac{R_1}{R_2}\right) V_{in}$$

Differentiation & Integration Configs.

- What are these used for?
  - Integrate or differentiate a signal
    - Used for I or D control
    - This is how PID controllers were primarily built
      - Not used as much now due to microcontrollers and computers
      - But some electronics are too “fast” for computer, so they must still be done in analog

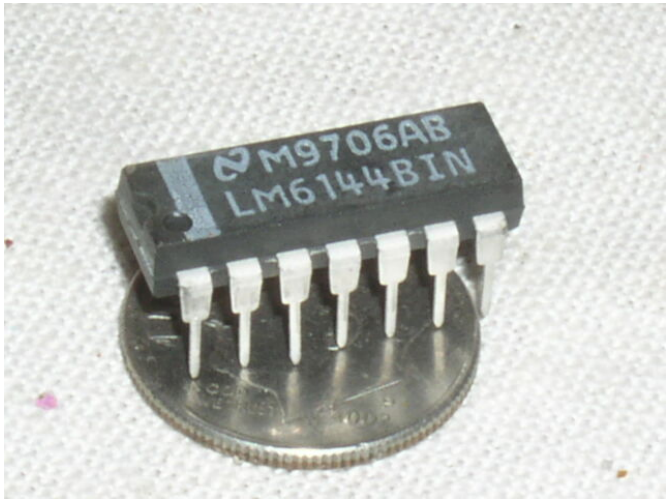


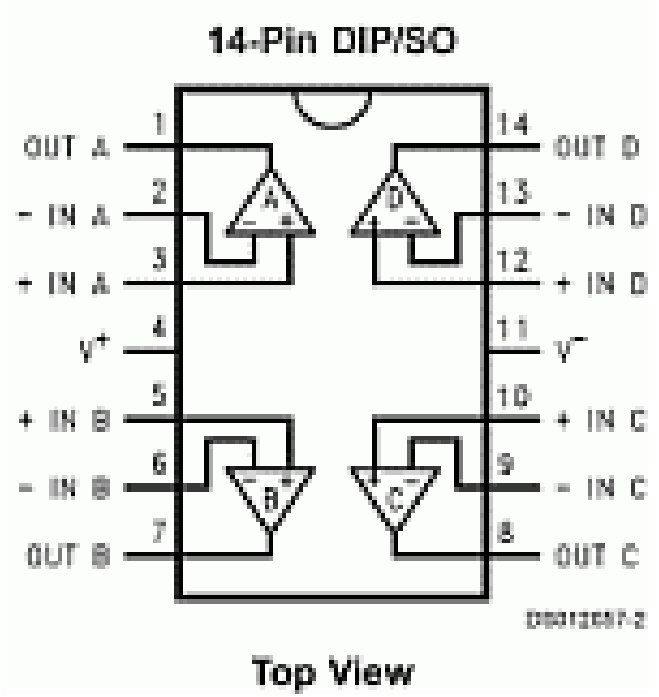
$$V_{OUT} = -RC \frac{dV_{IN}}{dt}$$



$$V_{OUT} = \frac{1}{RC} \int V_{IN}\, dt + \text{constant}$$

TI LM6144 Quad Op-AMP





At V_S = 5V. Typ Unless Noted.

- Rail-to-rail Input CMVR −0.25V to 5.25V
- Rail-to-Rail Output Swing 0.005V to 4.995V
- Wide Gain-Bandwidth: 17MHz at 50kHz (typ)
- Slew Rate:
  - Small Signal, 5V/µs
  - Large Signal, 30V/µs
- Low Supply Current 650µA/Amplifier
- Wide Supply Range 1.8V to 24V
- CMRR 107dB
- Gain 108dB with R_L = 10k
- PSRR 87dB