NATCAR – Background Information
Lecture #2
Power Conditioning Circuits

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Outline

- Power conditioning
- DC-to-DC conversion
- Switching regulators
- Linear regulators

Power Conditioning

- Your car must run from a single 7.2 V battery.
  - The battery voltage is *not* 7.2 V. It is around 8 V when fully charged and around 5 V when discharged enough that it won't supply sufficient current to run the car.
  - The battery has internal resistance. When the motor current pulses on (assuming PWM motor drive), the battery voltage typically drops by about 1 or 2 V.
- You need stable, noise free supplies for your electronics (+5 V, possibly -5 V, and possibly > +13 V if you use an H-bridge motor drive).
- We derive the required supplies from the battery using DC-to-DC converters.

Power Conditioning Continued

Problem:

We can make DC-to-DC converters that will step the input voltage up or down, or invert it. But, converters that step the voltage down often only work when the input is some amount higher than the output (called *headroom*). Therefore, we don't directly step the battery voltage down to 5 V or the battery will not be usable once its open-circuit voltage drops much below 8 V (remember it can drop by an additional 2 V when the motor current kicks on).

Solution:

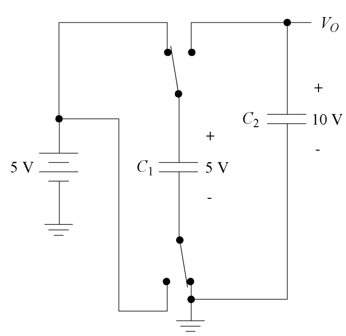
We can solve this problem by stepping the voltage up to +9 V first and then stepping that voltage back down to +5 V.

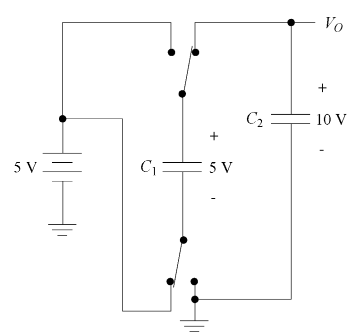
DC-to-DC Conversion

- There are two general techniques commonly used for DC-to-DC converters:
  1) Switched capacitor circuits
  2) Inductive circuits (called switching regulators)
- Switched capacitor circuits work by putting two or more capacitors in parallel, charging them up to the supply voltage, switching them in series, and transferring the new, higher, voltage to a hold capacitor. They are inefficient and only useful when small currents are needed – an example is shown on the next slide …

Capacitive Voltage Doubler

- By switching back and forth between the two phases shown, the supply voltage is doubled (you can also make a negative supply from a positive one and multiply by much more than 2)

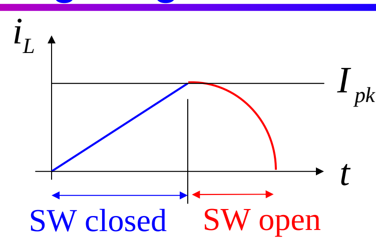




DC-to-DC Conversion

- There are two general techniques commonly used for DC-to-DC converters:
  1) Switched capacitor circuits
  2) Inductive circuits (called switching regulators)
- We will use inductive switching regulators. An inverting regulator example is shown next.

Inverting Switching Regulator



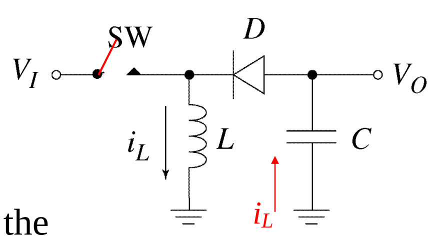
SW closed:

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.

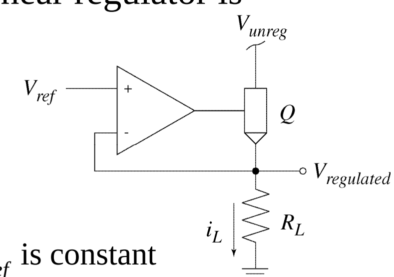
Feedback is used to control the switch and stop charging when the desired output voltage is reached.

Linear Voltage Regulators

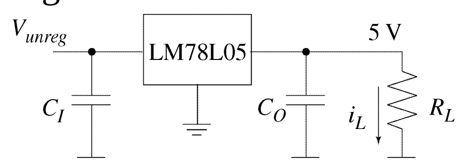
- Switching regulators are *nonlinear* circuits.
- Many voltage regulators are *linear* regulators.
- Linear regulators use negative feedback and a voltage reference to produce a stable output voltage.
  - the reference is easier to make stable since it doesn't need to supply much power
  - negative feedback is used to force the final regulated voltage to be close to the reference
  - the control element can be in series or parallel with the load

Linear Voltage Regulators Continued

- The basic principle of a series linear regulator is shown here:
  - i_L may vary, but we still have
    $$V_{regulated} = V_{ref}$$
  - Q is the *pass* transistor, it may be a BJT or MOSFET
  - V_{unreg} can vary too so long as V_{ref} is constant



- Once we have our +9 V supply, we can use a simple 3-terminal linear regulator to get +5 V.
  - C_I typically 0.33 μF
  - C_O typically 0.1 μF
  - $V_{unreg} \geq 7$ V



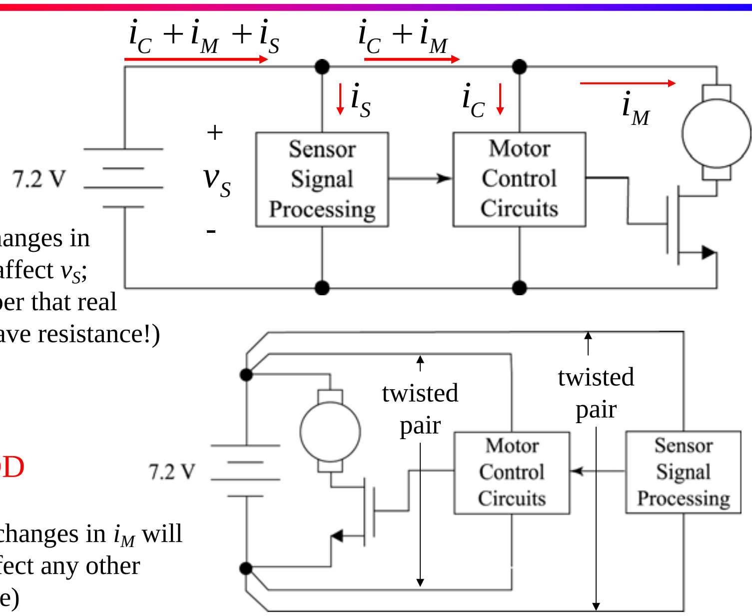
Practical Notes on Power Conditioning

- Be sure to carefully think through the grounding and layout
  - avoid long ground chains (as noted in previous lecture)
  - avoid loops that can pick up magnetic fields (use twisted pairs when possible as noted before)
- Just to remind you, and reinforce an important point, the following slide is a repeat from a previous lecture that illustrates these points

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)

Practical Notes on Power Conditioning

- Be sure to include bypass capacitors in your design
  - you should bypass the supply lines at all critical points in the circuit
  - remember to bypass reference voltages that you set with dividers too!