15 - Voltage Regulators

CEG 4330/6330 - Microprocessor-Based Embedded Systems

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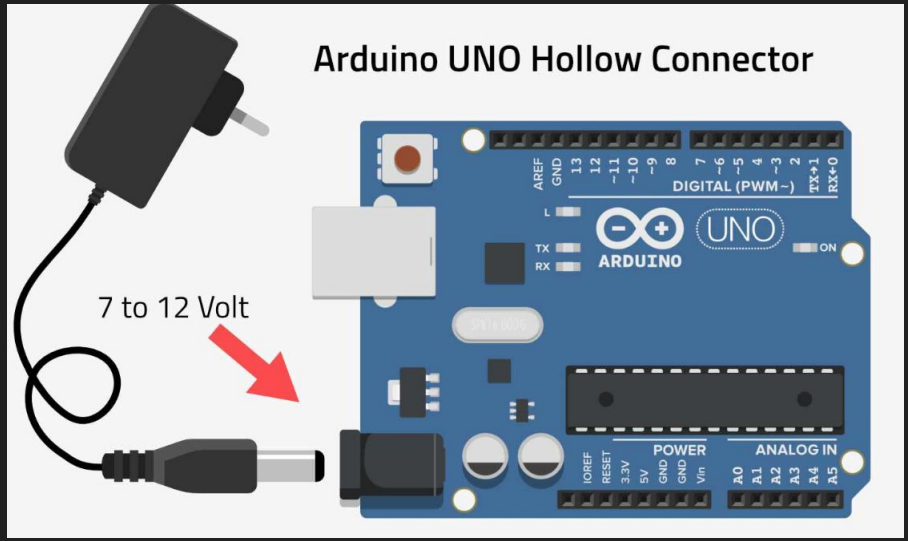
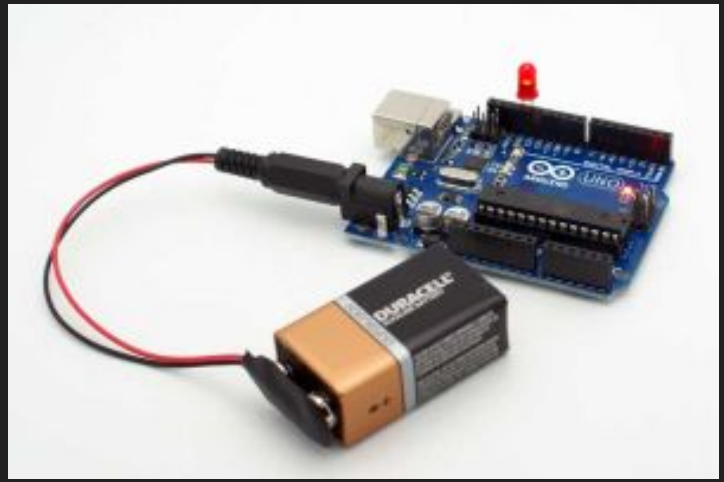
Regulating Voltage

- All microcontrollers and microprocessors require power to run
- The power is delivered by one or more voltage supplies
- These voltage supplies need to run at a specific voltage the microcontroller or microprocessor has been designed to use
- Thus, we will need some form of a regulated voltage supply

Regulating Voltage (cont.)

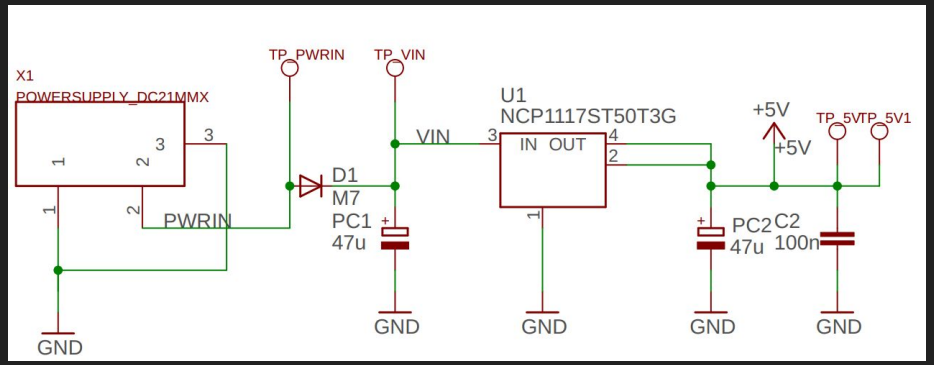
- Voltage regulation is typically handled on the circuit board for the embedded system itself
- This makes connecting the embedded system to a main power source much simpler
  - Example: The Arduino's microcontroller requires 5V
  - You can power the Arduino board with 7V to 12V because it gets regulated down to 5V





Arduino Uno Voltage Regulator

- The input voltage for the Arduino board is 7V to 12V recommended (20V max)
- The voltage regulator (U1) takes this input voltage and converts it to 5V

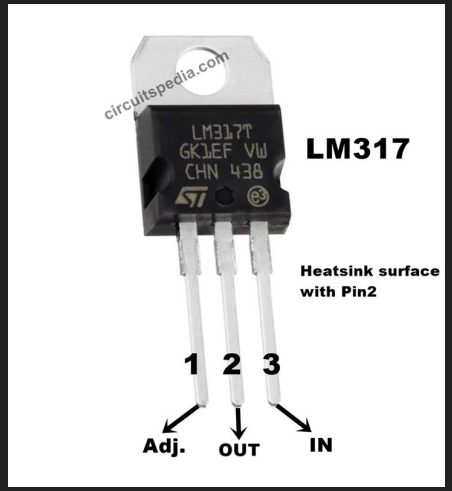


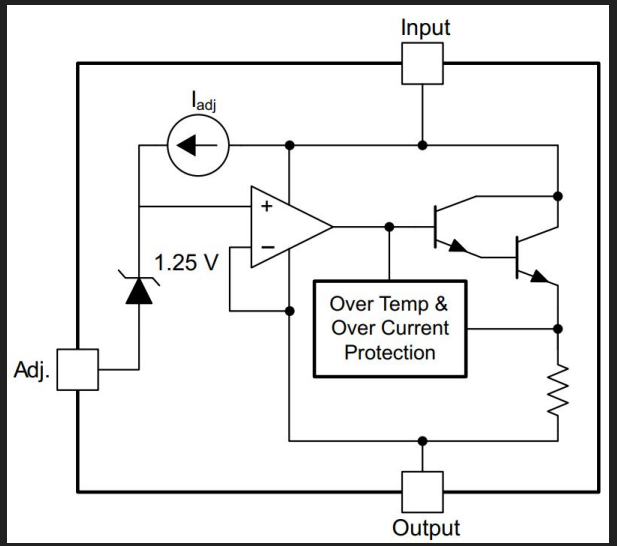
Types of Voltage Regulators

- There are 3 different types of voltage regulators
  - Linear Regulator
    - Low efficiency (wastes power by itself) but simple
  - LDO (Low Dropout Linear Regulator)
    - Medium efficiency also simple
    - Best used with Vin is very close to Vout
  - Switching Regulator
    - Highest efficiency but more complex

Linear Regulator

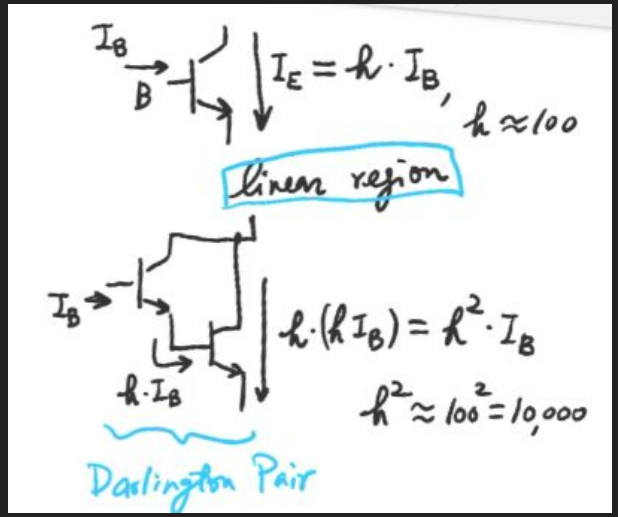
- A linear regulator will regulate a wide range of input voltages to some output voltage
- If you do not require efficiency and want a simple design with a high input range, a linear regulator is great
- LM317 is common linear regulator that has an adjustable output voltage
  - Input voltage: 4.25V to 40V
  - Output voltage: 1.25V to 37V

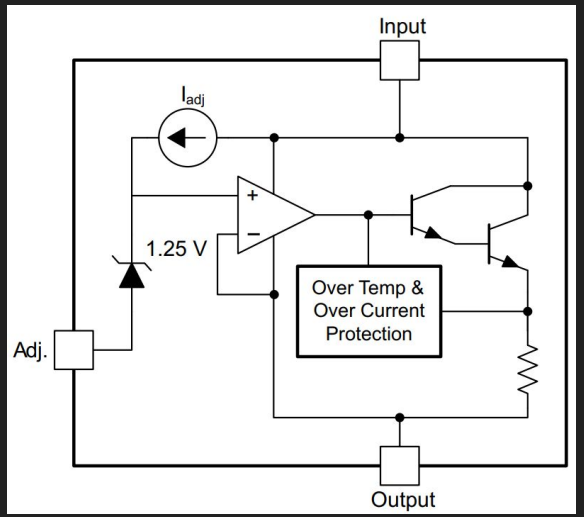




Linear Regulator (cont.)

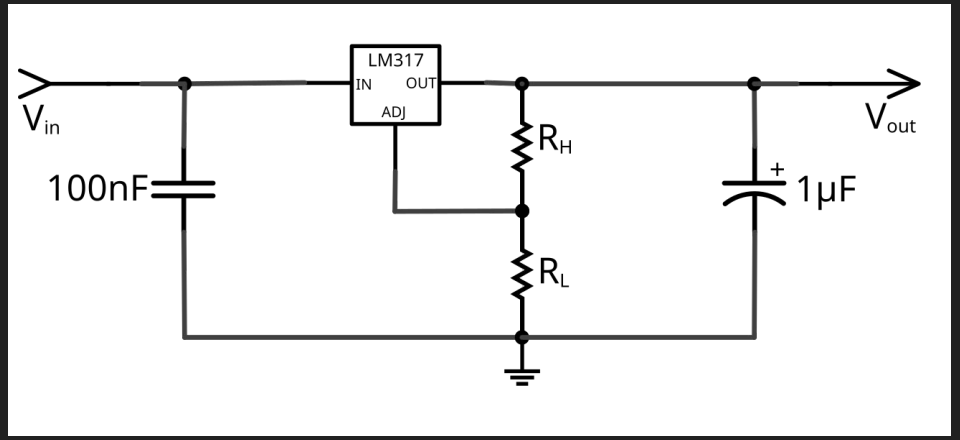
- A linear regulator works by exploiting the linear region of transistors in a Darlington Pair
- The linear region of transistor operation is where the output current has a linear relationship to input current
- The Darlington Pair allows for very small amounts of current to control large amounts of current
- The Zener diode provides a fixed reference for the regulator’s feedback loop





LM317 Circuit

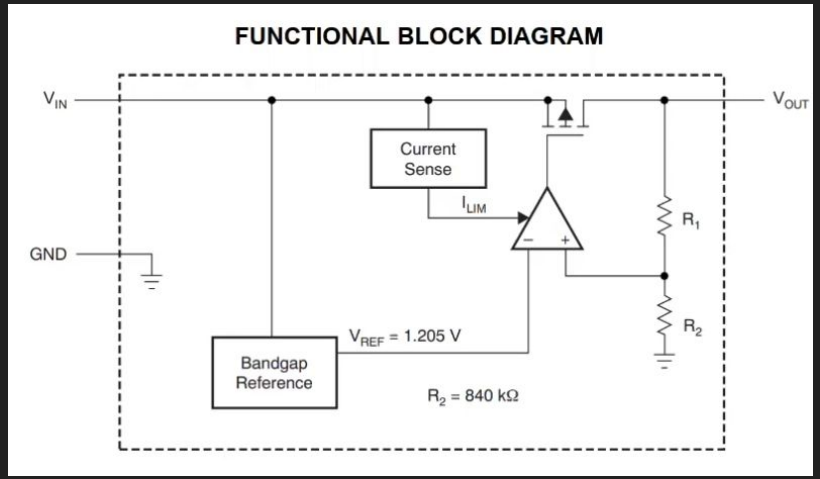
- A circuit for the LM317 is shown
  - Under typical operation Vref is 1.25V
  - To regulate a certain output voltage, you must select RL and RH
- Select resistors for Vout = 5V
  - What is the range for Vin?

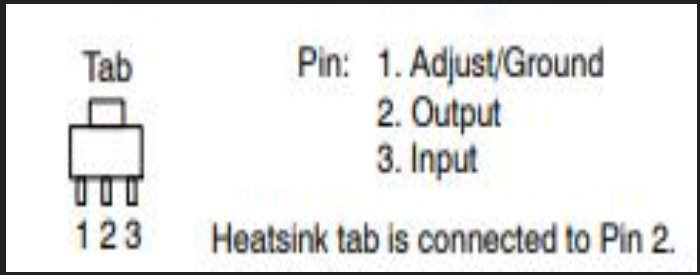


$$V_{out} = V_{ref}\left(1 + \frac{R_L}{R_H}\right)$$

Low Dropout Linear Regulator (LDO)

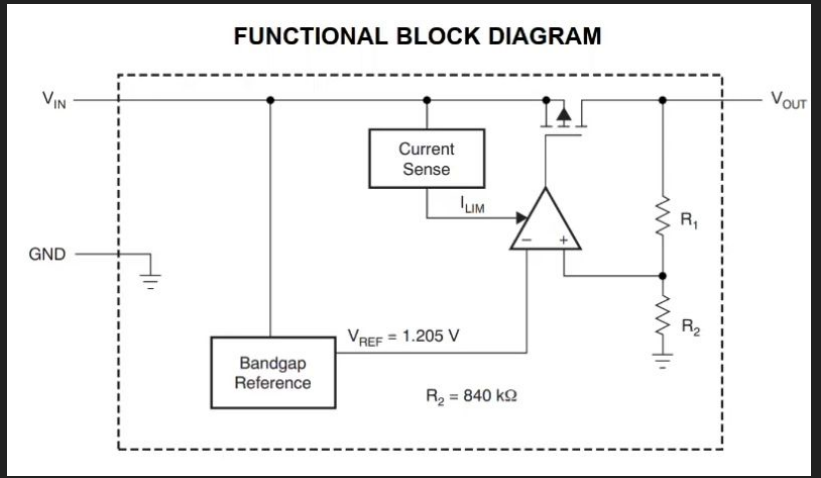
- A low dropout linear regulator (LDO) is another form of linear regulator
- It is designed to have very low dropout
  - Dropout is the minimum Vin - Vout while still achieving desired regulation
- NCP1117 is used by the Arduino board





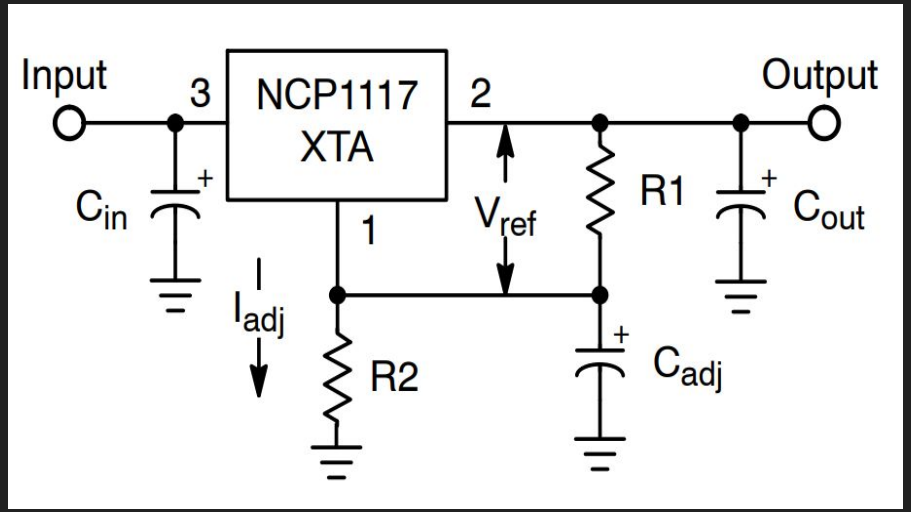
Low Dropout Linear Regulator (LDO) (cont.)

- LDOs are more efficient because their voltage drop is lower:
  - P = I * V
  - I = load current
  - V = Vin - Vout
    - If Vin = Vout, no power consumption!
  - Efficiency = Pout / Pin
    - Current is typically equally for input and output
- For this reason, it is much better to select an LDO if Vin is very close to Vout



NCP1117 Circuit

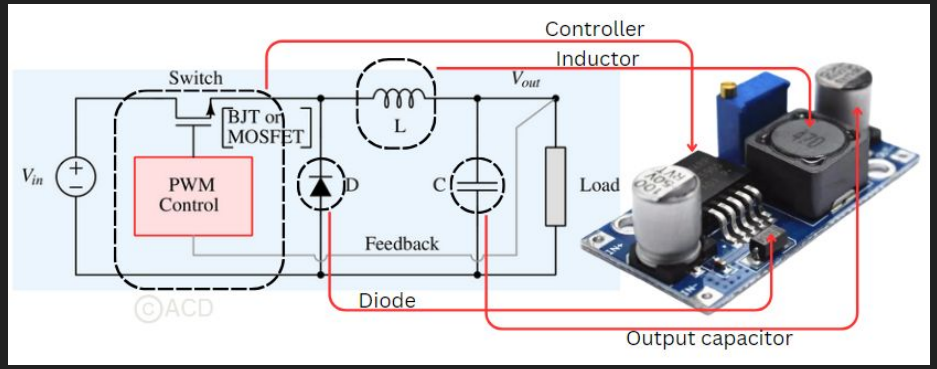
- A circuit for the NCP1117 is shown
  - Under typical operation Vref is 1.25V
  - To regulate a certain output voltage, you must select R1 and R2
- Select resistors for Vout = 5V
  - What is the range for Vin?

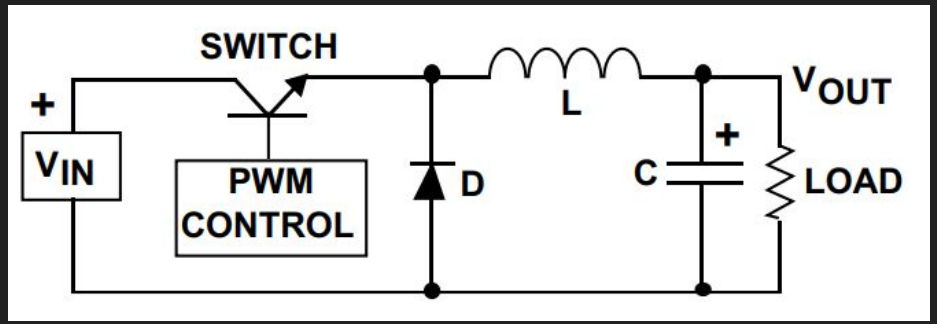


$$V_{out} = V_{ref}\left(1 + \frac{R2}{R1}\right)$$

Switching Regulator

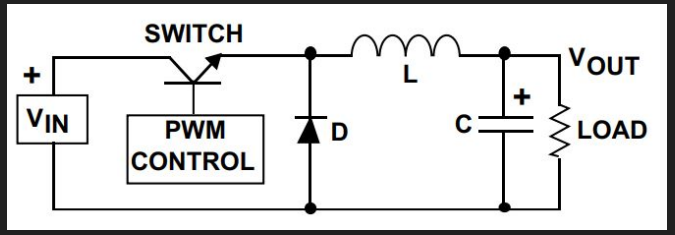
- A switching regulator works on the principle of V = L di/dt for an inductor
- Very efficient, but creates a lot of noise
- Output voltage can be higher (boost), or lower (buck), or even negative

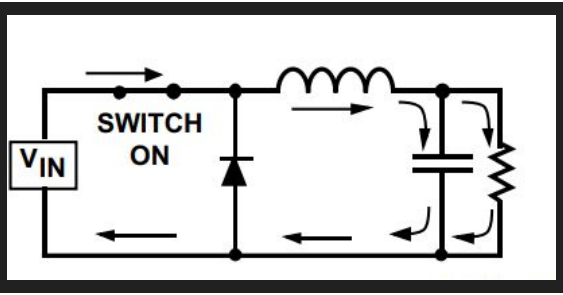


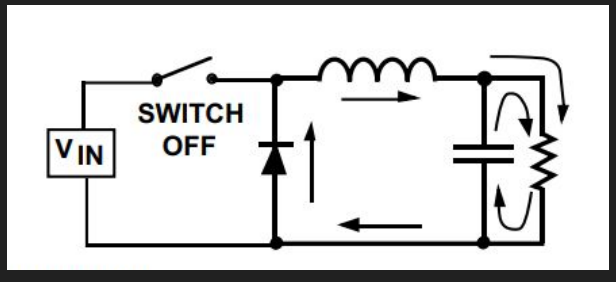


Buck Regulator

- A buck regulator is a type of switching regulator
  - Also called step down
  - Regulates a Vout < Vin
- Highly efficient because inductor and capacitor consume no power but diode consumes a little power
- V_L = Vin - Vout
- Vout = Vin - V_L
- Vout = Vin - L di/dt
- Try it yourself: https://tinyurl.com/236sd32t







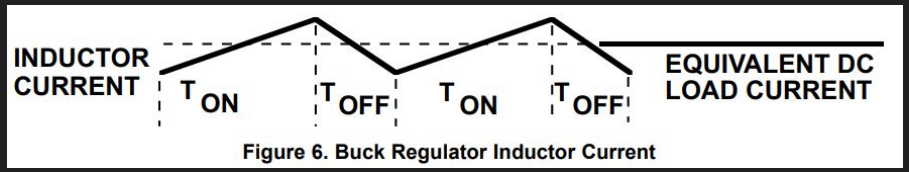


Figure 6. Buck Regulator Inductor Current

Boost Regulator

- A boost regulator is a type of switching regulator
  - Also called step up
  - Regulates a Vout > Vin
- Also highly efficient
- When the switch opens, the inductor induces a voltage, causing a rise in voltage in Vout
- Try for yourself: https://tinyurl.com/2279hfbn