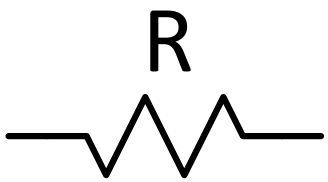
CLASS 4: ELECTRICAL RESISTANCE

ENGR 102 – Introduction to Engineering

Resistance & Conductance

Resistance

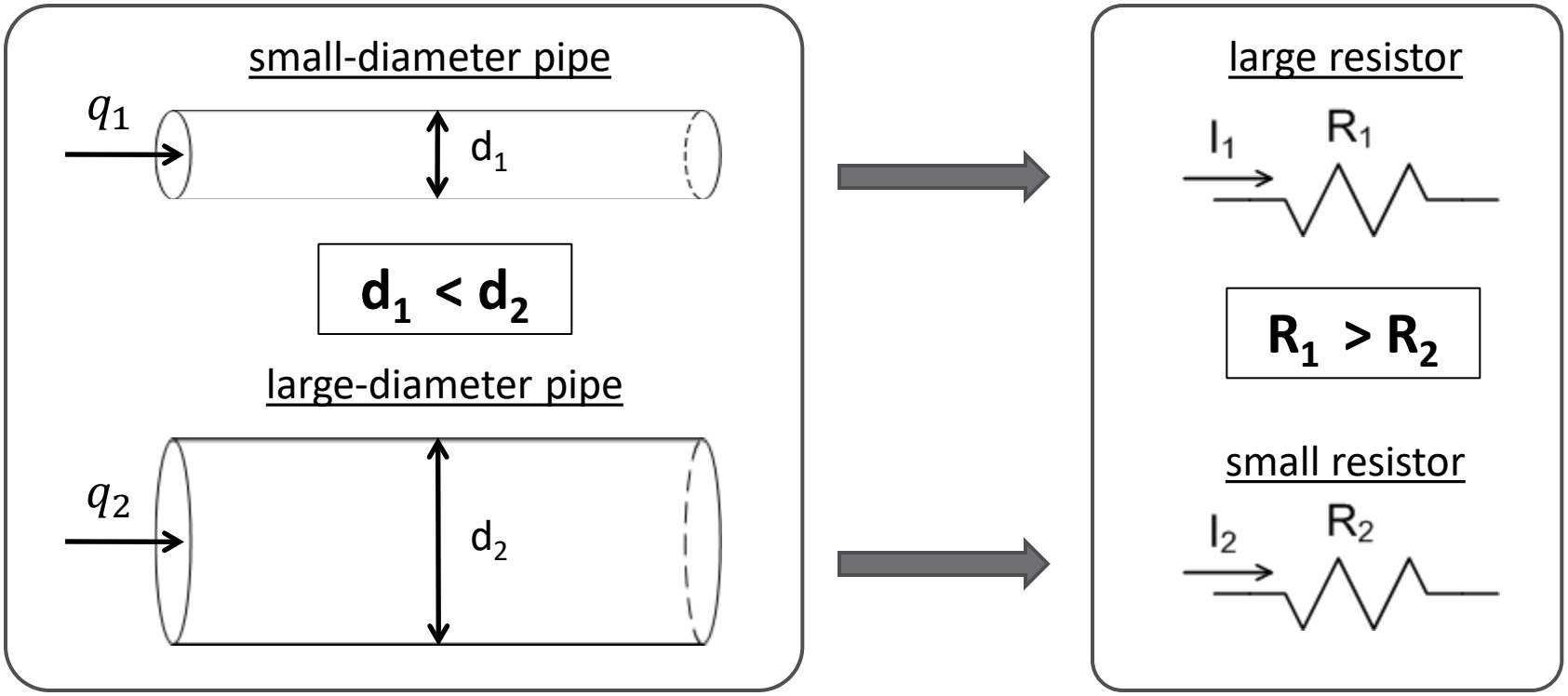
- ***Resistance***
  - The degree to which a circuit element opposes the flow of electrical current
- Schematic symbol:



- Units: ohms (Ω)
- May be discrete, intentional circuit components, or parasitic resistance of wires, cables, interconnects, etc.

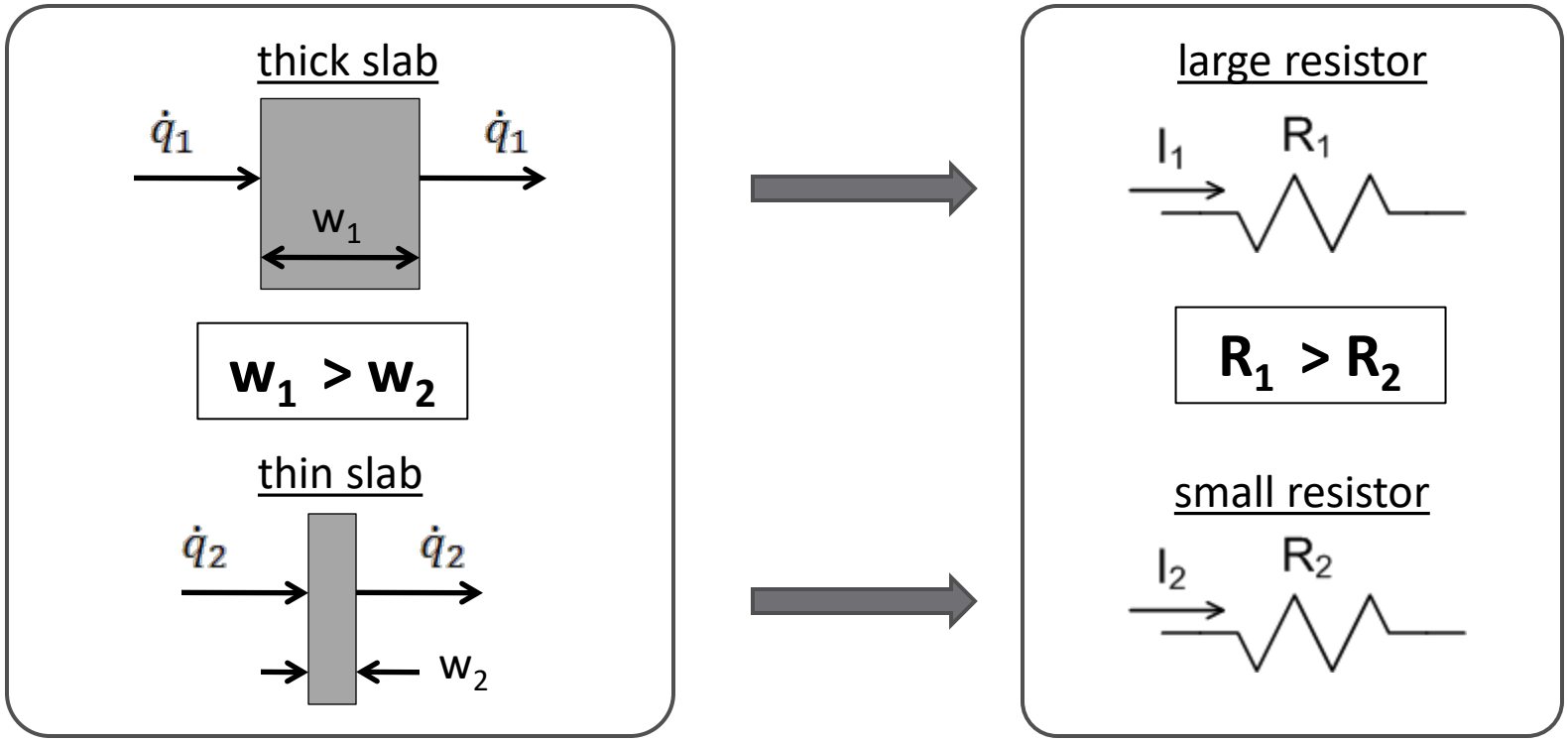
Resistance – Fluid Analogy

- Electrical resistance is analogous to the resistance of a pipe to fluid flow due to friction



Resistance – Thermal Analogy

- Electrical resistance is analogous to the resistance of heat conduction through a solid

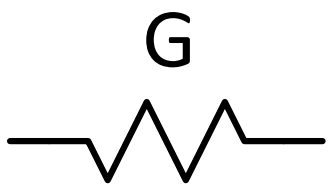


Conductance

- Electrical **conductance** is the degree to which a circuit element allows the flow of electrical current
- Conductance is the **inverse of resistance**

$$G = \frac{1}{R}$$

- Schematic symbol:



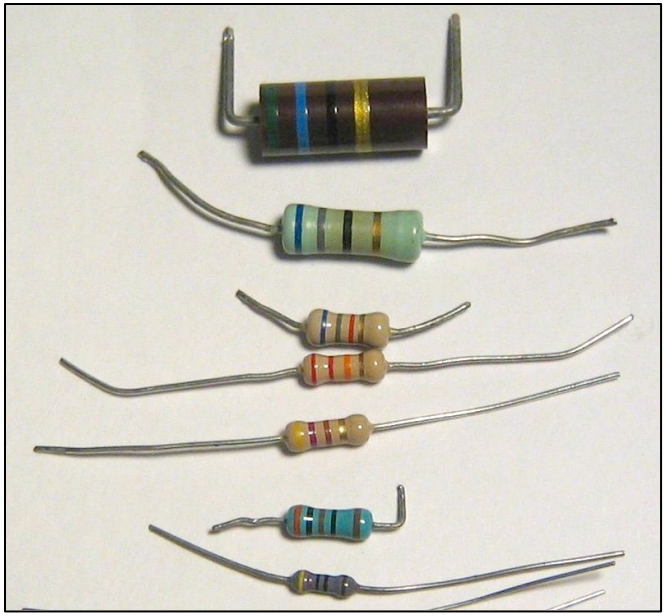
- Units: **siemens** or **mhos** (S or Ω^{-1})

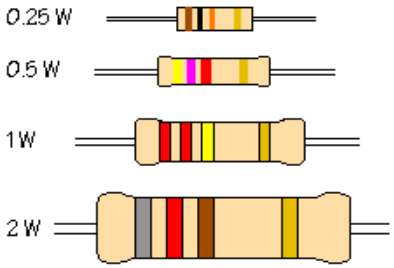
Real Resistors

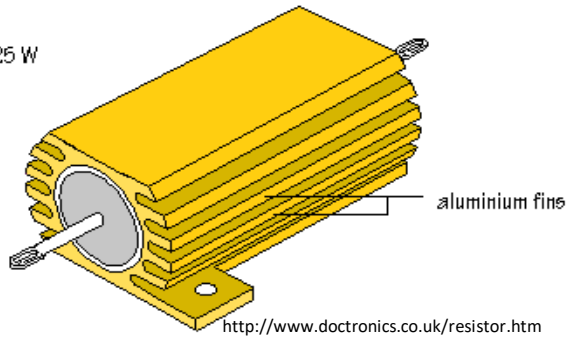
- Resistors for use in electronic circuits come in many shapes and sizes depending on their target application
- Size primarily determined by power handling capability
  - Larger resistors can dissipate more power
- Two primary form factors:
  - ***Axial lead*** resistors
  - ***Chip*** resistors

Axial Lead resistors

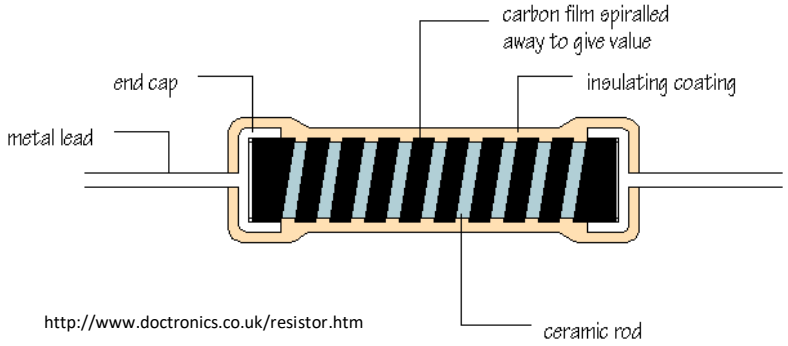
- Cylindrical resistive component with wire leads extending from each end
- Used with **through-hole technology** printed circuit boards (PCB's)
  - Useful for prototyping
  - Size varies with power handling capacity







http://www.doctronics.co.uk/resistor.htm



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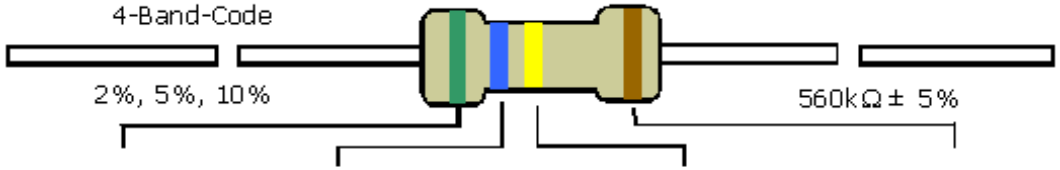
Resistor Color Code

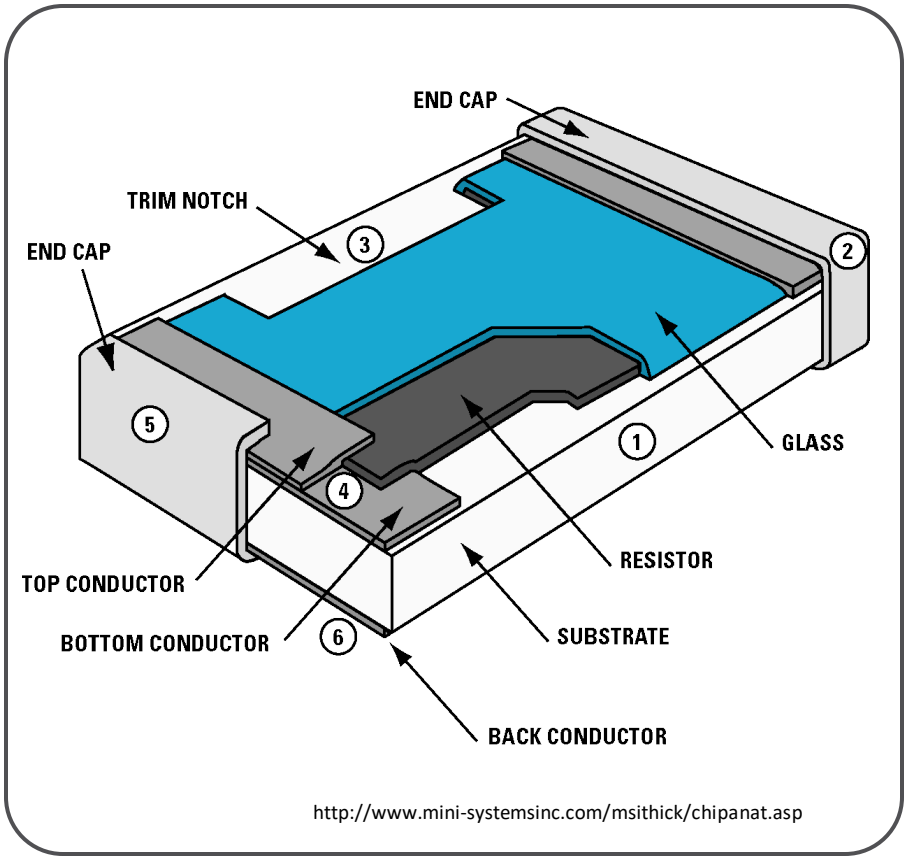


COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE	
Black	0	0	0	1Ω		
Brown	1	1	1	10Ω	± 1%	(F)
Red	2	2	2	100Ω	± 2%	(G)
Orange	3	3	3	1KΩ		
Yellow	4	4	4	10KΩ		
Green	5	5	5	100KΩ	±0.5%	(D)
Blue	6	6	6	1MΩ	±0.25%	(C)
Violet	7	7	7	10MΩ	±0.10%	(B)
Grey	8	8	8		±0.05%	
White	9	9	9			
Gold				0.1	± 5%	(J)
Silver				0.01	± 10%	(K)

http://www.elexp.com/t_resist.htm

Chip Resistors

- Small rectangular footprint
  - 0805 – 0.080” x 0.050”
  - 0603 – 0.060” x 0.030”
  - 0402 – 0.040” x 0.020”
  - 0201 – 0.020” x 0.010”
- Used with **surface-mount technology** PCB’s
- More common than axial lead in modern electronics



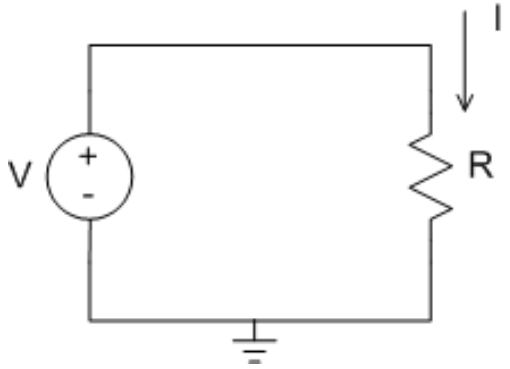
http://www.mini-systemsinc.com/msithick/chipanat.asp

Ohm's Law

Ohm's Law

Georg Simon Ohm, 1789 – 1854

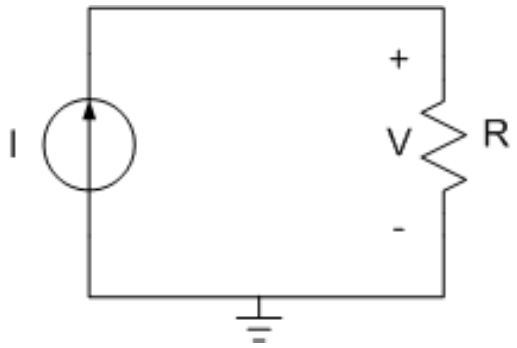
$$I = \frac{V}{R}$$



"The current through a resistor is proportional to the voltage across the resistor and inversely proportional to the resistance."

Ohm's Law – said differently

$$V = I \cdot R$$



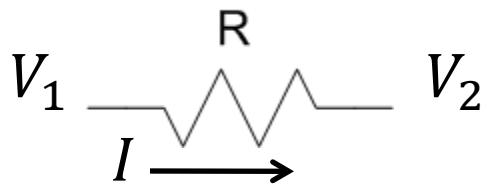
Georg Simon Ohm, 1789 – 1854

"The voltage across a resistor is proportional to the current through the resistor and proportional to the resistance."

Ohm's Law – fluid analogy

- ***Voltage*** is analogous to ***pressure***
  - Driving potentials
- Electrical ***current*** is analogous to ***flow rate***
- A pipe carrying fluid has some resistance determined by physical characteristics (length, diameter, roughness, etc.)

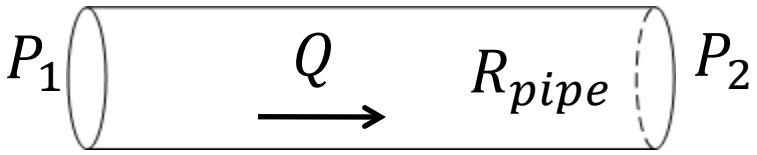
Resistor



$$I \propto (V_1 - V_2), \qquad I \propto \frac{1}{R}$$

$$(V_1 - V_2) \propto I, \qquad (V_1 - V_2) \propto R$$

Section of pipe



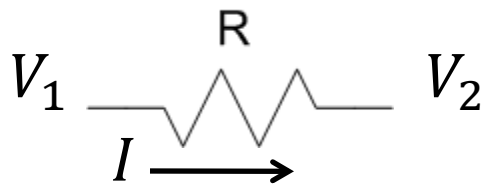
$$Q \propto (P_1 - P_2), \qquad Q \propto \frac{1}{R_{pipe}}$$

$$(P_1 - P_2) \propto Q, \qquad (P_1 - P_2) \propto R_{pipe}$$

Ohm's Law – thermal analogy

- **Voltage** is analogous to **temperature**
  - Driving potentials
- Electrical **current** is analogous to **heat flux**
- A solid slab or wall has some thermal resistance determined by physical characteristics (thickness, material properties, etc.)

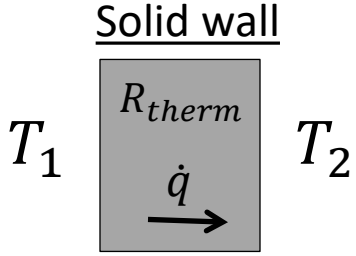
Resistor



$$I \propto (V_1 - V_2), \qquad I \propto \frac{1}{R}$$

$$(V_1 - V_2) \propto I, \qquad (V_1 - V_2) \propto R$$

Solid wall



$$\dot{q} \propto (T_1 - T_2), \qquad \dot{q} \propto \frac{1}{R_{therm}}$$

$$(T_1 - T_2) \propto \dot{q}, \qquad (T_1 - T_2) \propto R_{therm}$$

Resistor Color Code

Exercise

- What are the values of the following resistors?

Ohm's Law

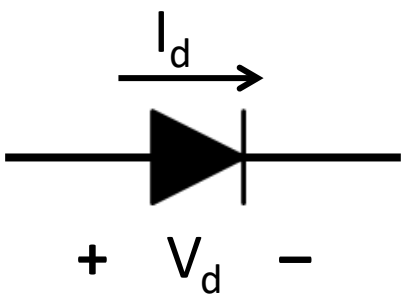
Exercise

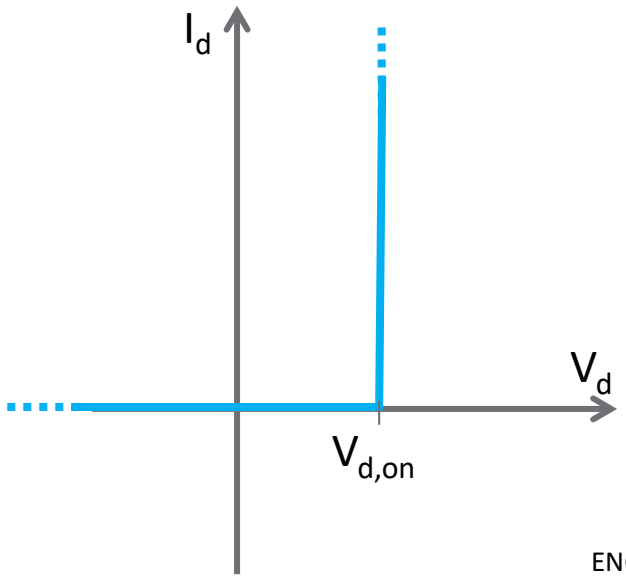
- A 1 kW space heater is plugged into a 120 V wall outlet. The resistive heating element in the heater has a resistance of 14 Ω.
  - How much current does the heater draw?

Diodes & LEDs

Exercise

- ***Diodes*** allow current to flow in one direction only
  - Diode is off ($I_d = 0$) when voltage is less than the ***turn-on voltage*** ($V_d < V_{d,on}$)
    - Typically, $V_{d,on} \approx 600 - 700\ mV$
  - When the diode is on ($I_d > 0$), diode voltage is approximately constant, independent of current ($V_d = V_{d,on}$)

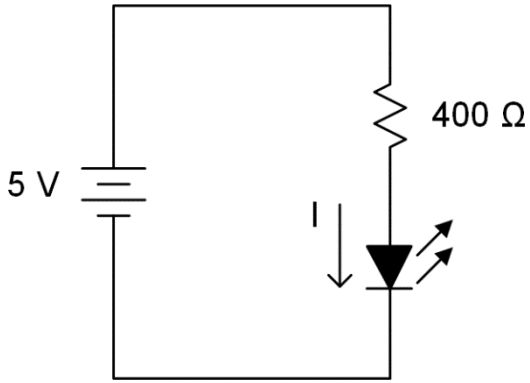




Diodes & LEDs

Exercise

- Light-emitting diodes (LEDs) behave the same way
- LED turn-on voltage depends on color
  - $V_{d,on} \approx 1.8\ V \ldots 3.6\ V$
- Determine the LED current in the circuit below
  - Assume $V_{d,on} = 2\ V$



Diodes & LEDs

Exercise

- Determine the value of the current-limiting resistor, R, below, such that $I = 18\ mA$
  - Assume $V_{d,on} = 2\ V$