

ECE 320 - Homework #6

Boolean Logic, DTL, TTL, Mosfets

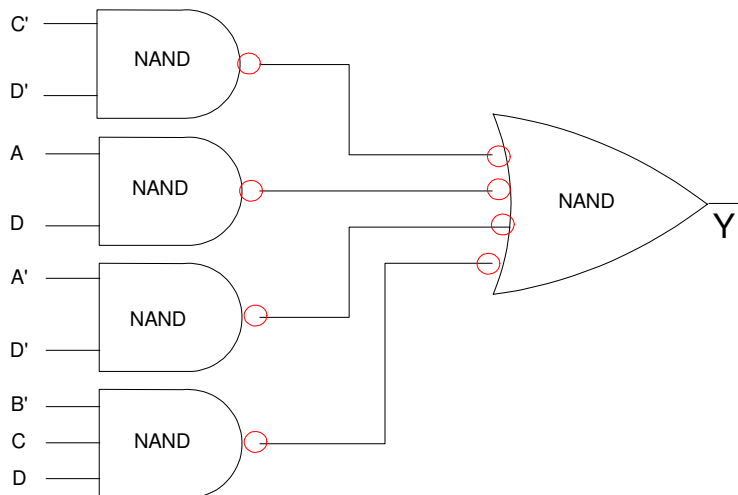
Boolean Logic

1) Design a circuit to implement Y using NAND gates

		CD			
		00	01	11	10
AB	00	1	0	1	x
	01	1	0	0	1
	11	1	1	1	0
	10	x	1	x	0

$$Y = C'D' + AD + A'D' + B'CD$$

Using NAND gates



2) Design a circuit to implement Y using NOR gates

		CD			
		00	01	11	10
AB	00	1	0	1	x
	01	1	0	0	1
	11	1	1	1	0
	10	x	1	x	0

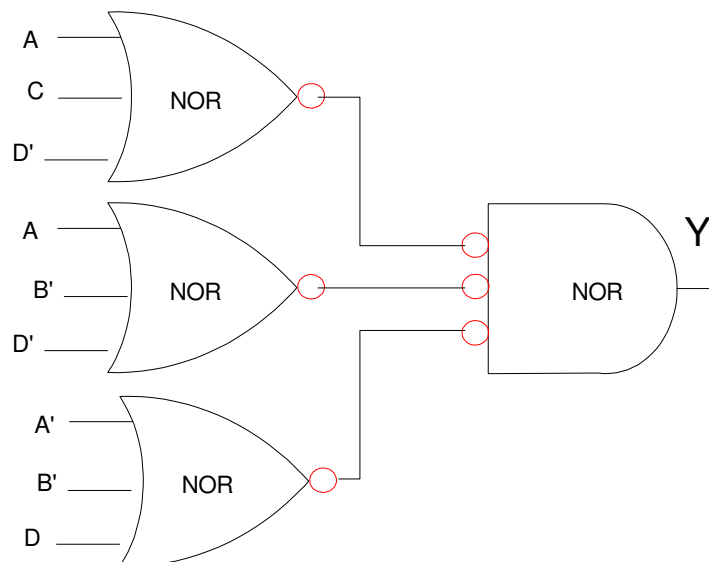
$$Y' = A'C'D + A'BD + ACD'$$

using DeMorgan's Theorem

$$Y = (A + C + D')(A + B' + D')(A' + C' + D)$$

Using NOR gates:

>



DTL Logic

3) Determine the voltages and currents for the following DTL OR gate

$$I_2 = \left(\frac{5V - 0.7V - 0.7V}{50k} \right) = 72\mu A$$

$$\beta I_2 = 14.4mA$$

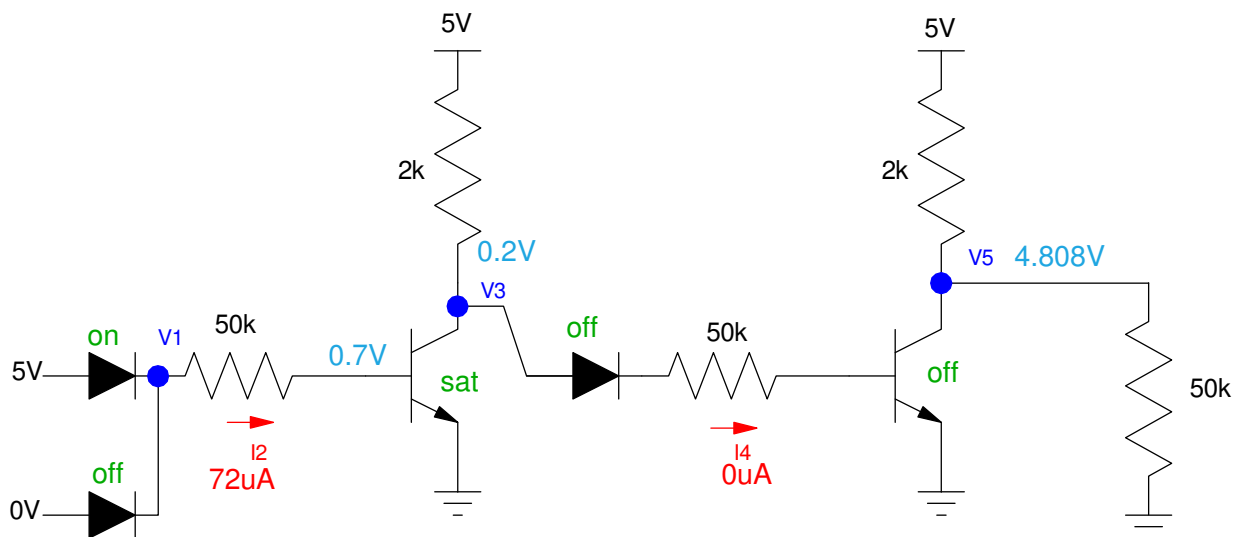
$$\max(I_c) = \left(\frac{5V - 0.2V}{2k} \right) = 2.40mA$$

$$\beta I_b > I_c$$

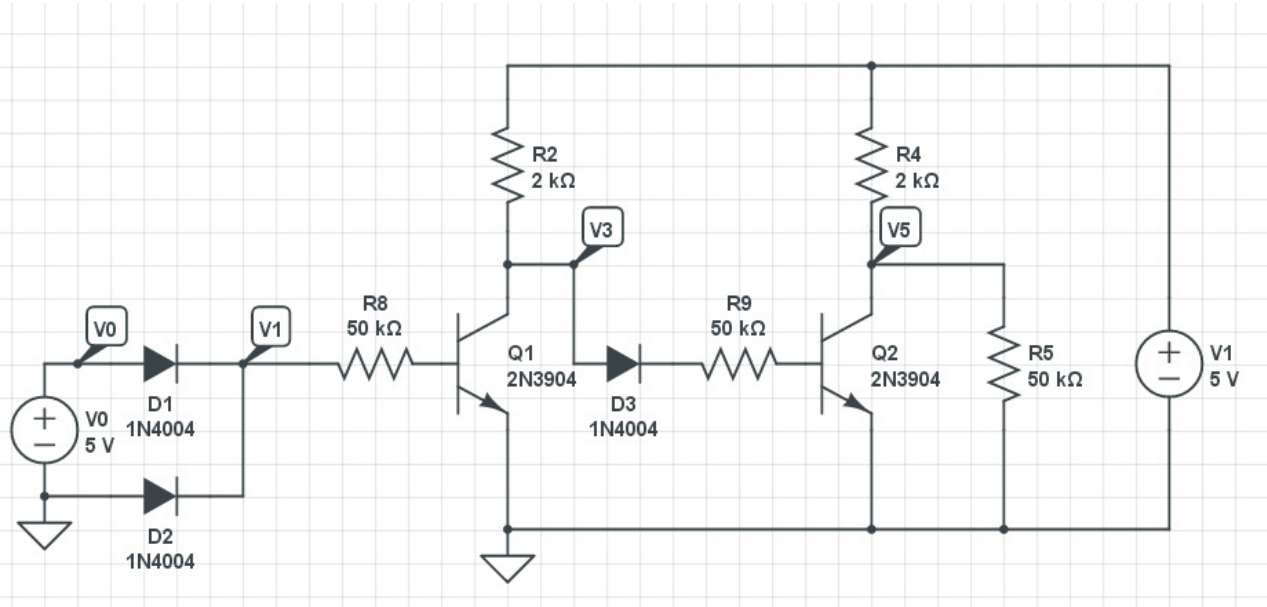
T1 is saturated

$$V_3 = 0.2V < 0.7V$$

T2 is off



4) Simulate this circuit in CircuitLab to verify your answers for problem #1



V(V1)	4.486 V		
V(V3)	66.70 mV		
V(V5)	4.808 V		
I(R8.nA)	75.96 μ A		
I(R2.nA)	2.467 mA		
I(R9.nA)	0.000 A		

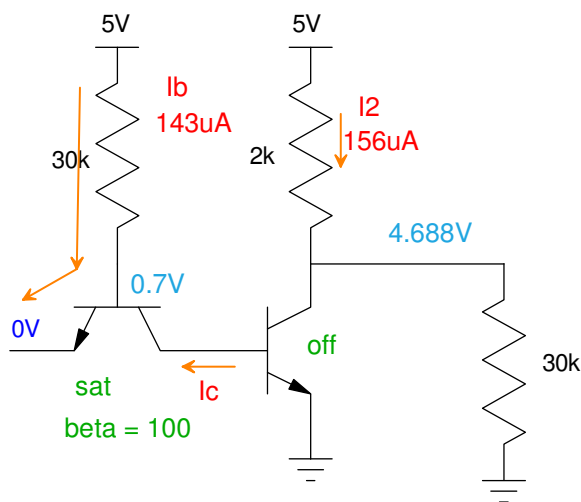
	Calculated	Simulated
V1	4.30V	4.486V
V3	0.20V	0.067V
V5	4.808V	4.808V
I(R8)	72 μ A	75.96 μ A
I(R2)	2.40mA	2.467mA
I(R9)	0	0

TTL Logic

5) Determine the voltages for the following TTL inverter. Assume 3904 transistors.

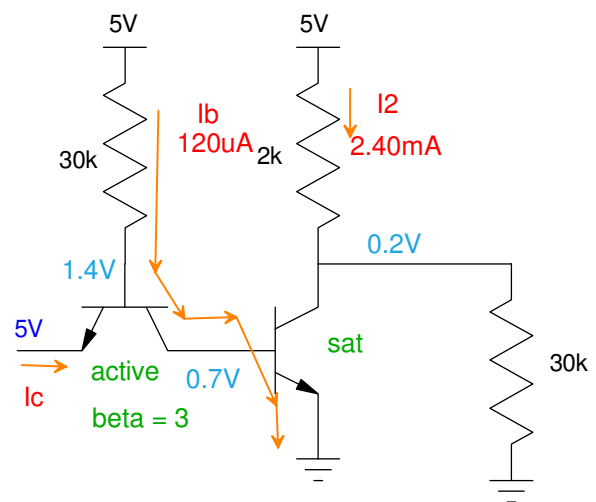
Left Circuit

- $I_b = \left(\frac{5V - 0.7V}{30k} \right) = 143\mu A$
- $I_c = 0$
- This turns on (saturates) T1
- $V_c = \left(\frac{30k}{30k + 2k} \right) 5V = 4.688V$
- $I_2 = \left(\frac{5V}{32k} \right) = 156\mu A$

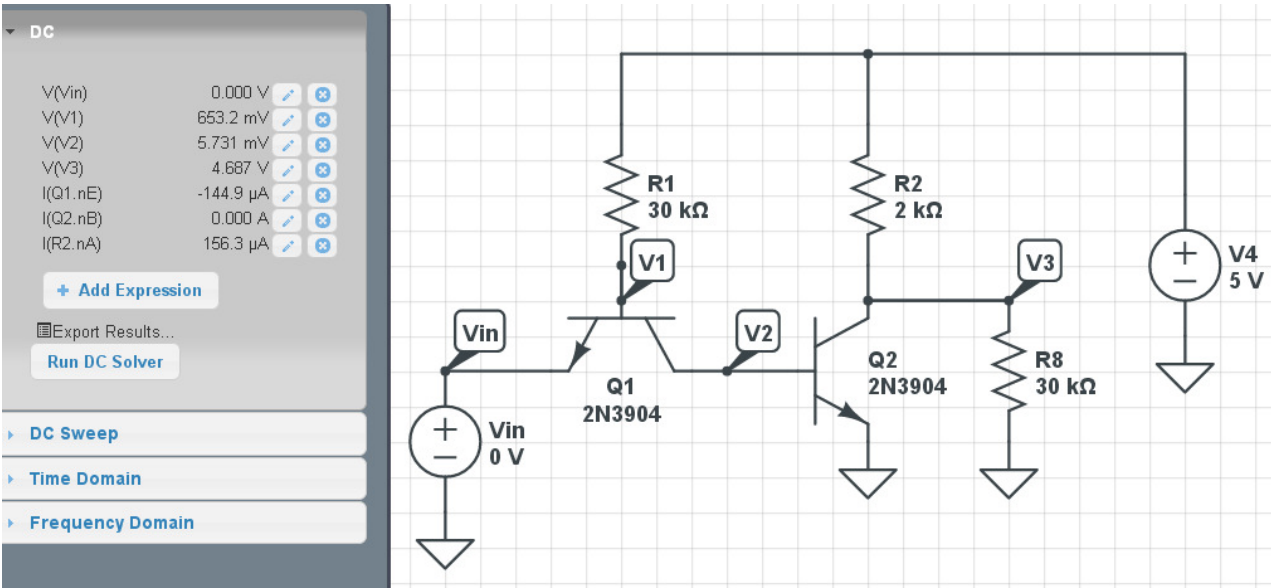


Right Circuit

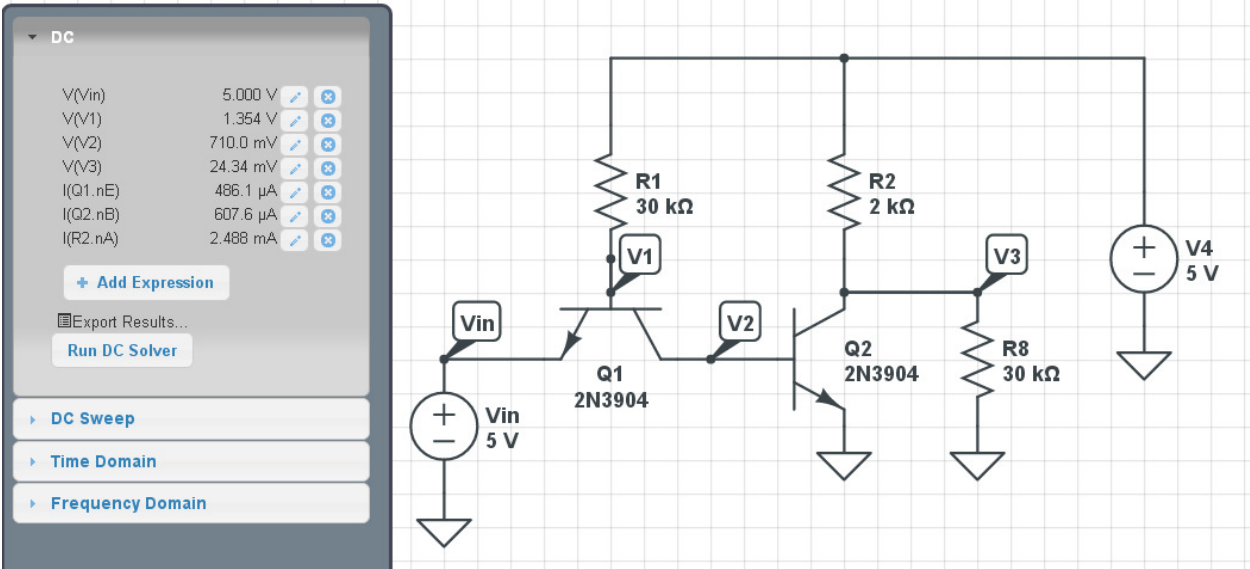
- $I_b = \left(\frac{5V - 1.4V}{30k} \right) = 120\mu A$
- $I_c = \beta I_b = 360\mu A$
- T2 now has a base current of 480uA
- which allows 48mA to flow
- $\max(I_2) = 2.40mA$ (T2 is saturated)



6) Simulate these circuits in CircuitLab and determine the voltage and currents



	V1	V2	V3	I(Q1.e)	I(Q2.b)	I(R2)
Calculated	0.7V	?	4.688V	143uA	0	156uA
Simulated	0.6532V	5.731V	4.687V	-144.9uA	0	156.3uA



	V1	V2	V3	I(Q1.e)	I(Q2.b)	I(R2)
Calculated	1.40V	0.70V	0.20V	360uA	480uA	2.40mA
Simulated	1.354V	0.710V	0.0234V	486uA	607uA	2.488mA

note: CircuitLab uses $\beta=5.00$ when used backwards for Q1

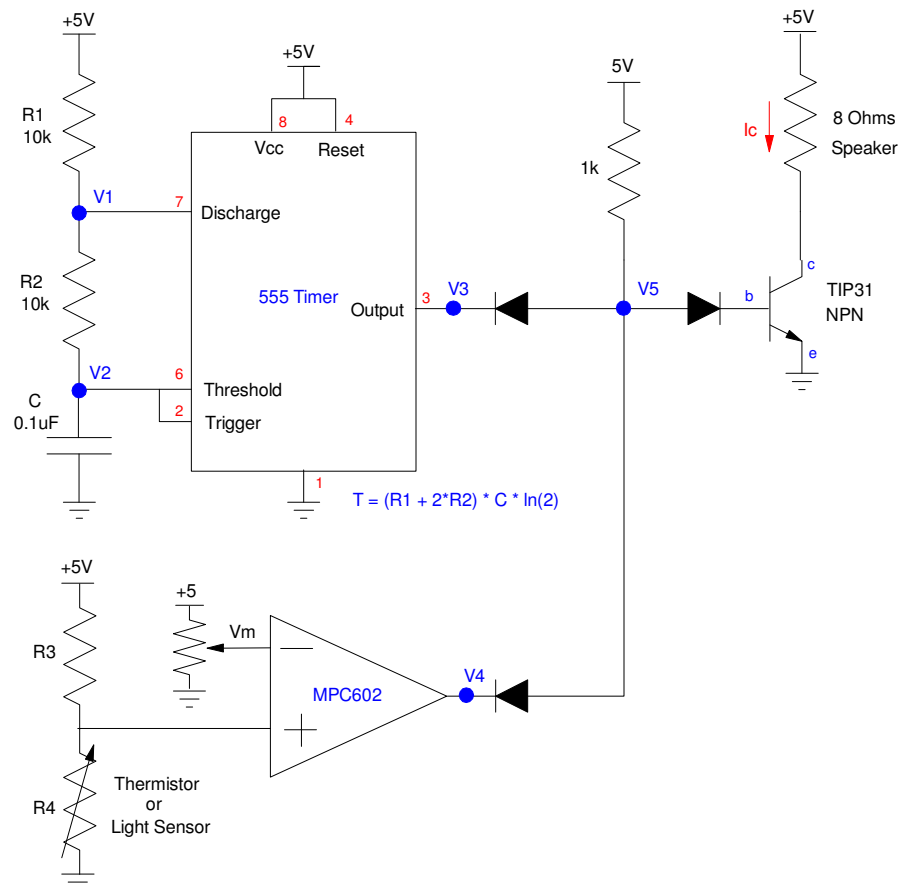
Temperature Alarm using DTL Logic

The circuit below uses a DTL NAND gate to drive the speaker when

- The 555 timer outputs 5V, and
- The comparator outputs 5V,.

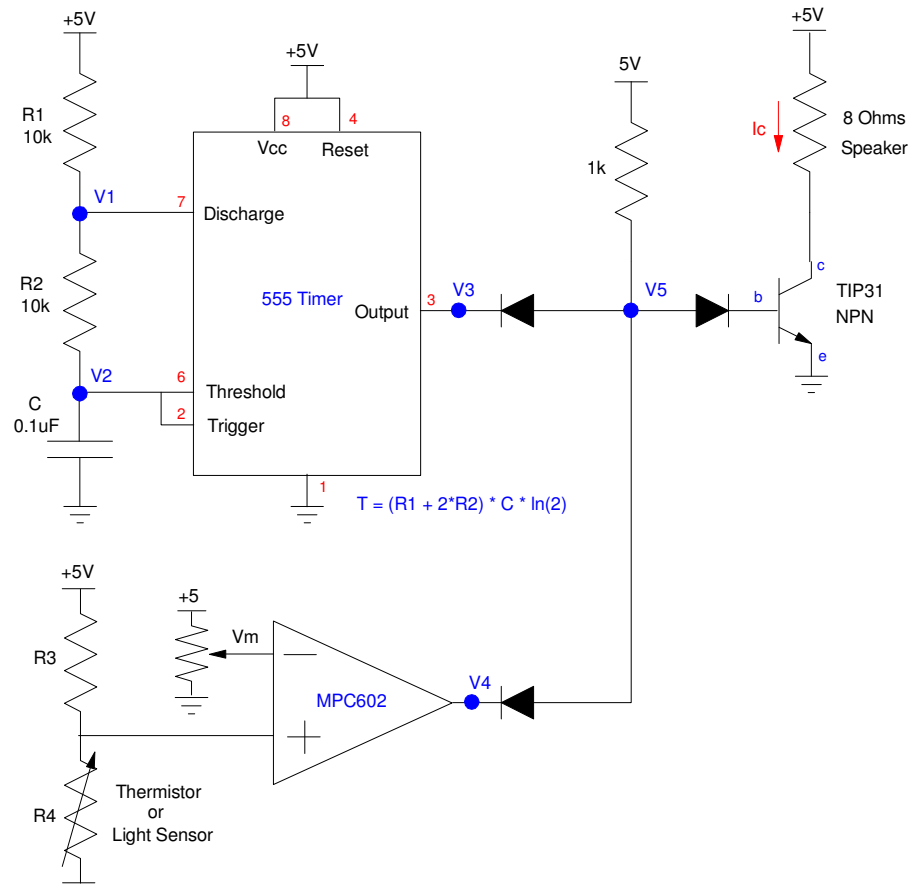
7a) Determine the voltages when $V_3 = V_4 = 0V$

- $V_5 = 0.7V$
- The TIP transistor is off
- $I_c = 0$
- note: this is the state if either V_3 or V_4 is logic zero (DTL AND gate)



7b) Determine the voltages when $V_3 = V_4 = 5V$

- $V_5 = 1.4V$
- The TIP transistor is on (saturated)
- $I_c = 600mA$



MOSFET

8) Label the operating regions on the graph below (off, ohmic, saturated) and determine the transconductance gain, k_n . Assume the turn-on voltage is $V_t = 1.00V$

To find k_n , pick a point. point A (Ohmic region)

$$I_{ds} = k_n \left(V_{gs} - V_{th} - \frac{V_{ds}}{2} \right) V_{ds}$$

$$600mA = k_n \left(7V - 1V - \frac{2V}{2} \right) 2V$$

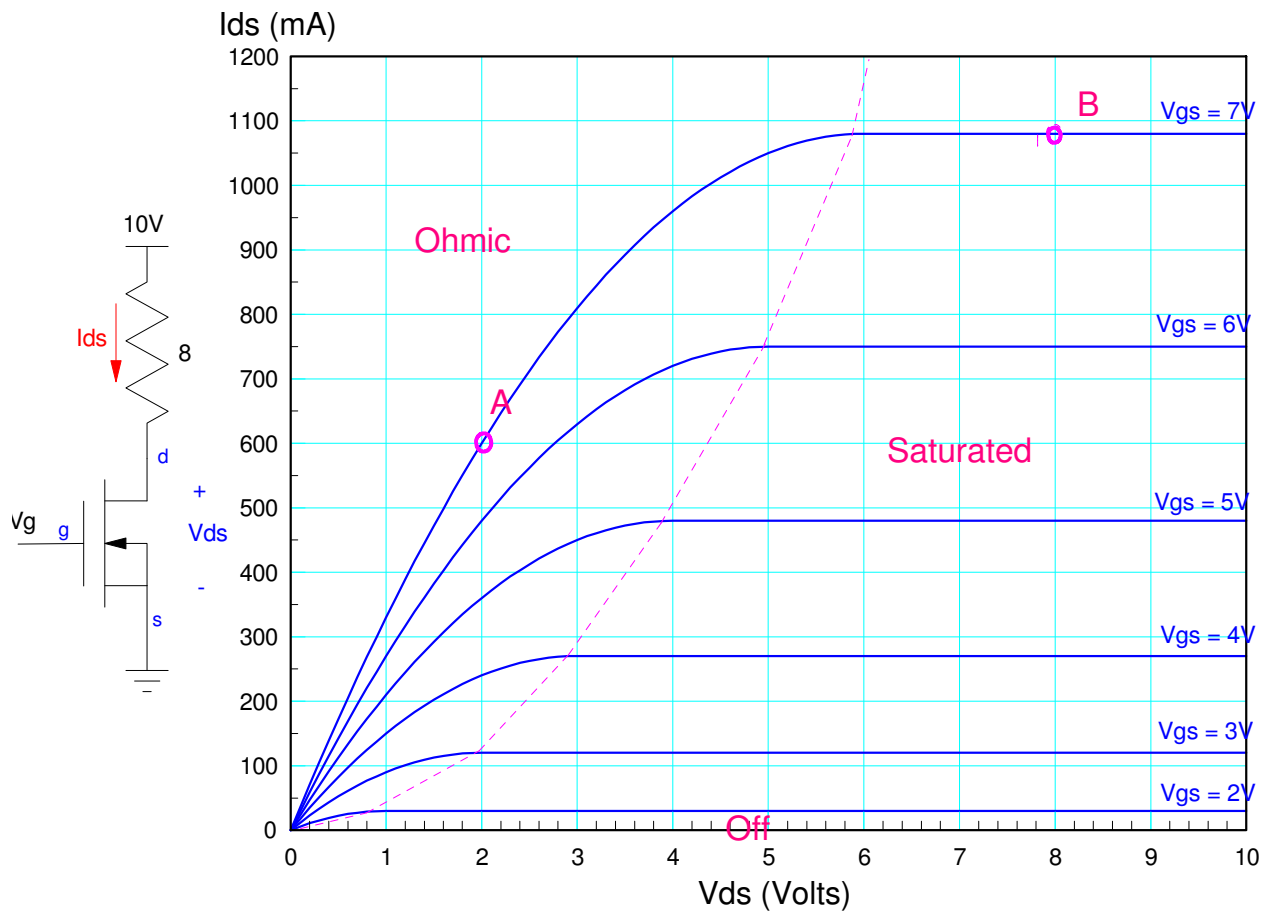
$$k_n = 0.060 \frac{A}{V^2}$$

Point B (Saturated revision)

$$I_{ds} = \frac{k_n}{2} (V_{gs} - V_{th})^2$$

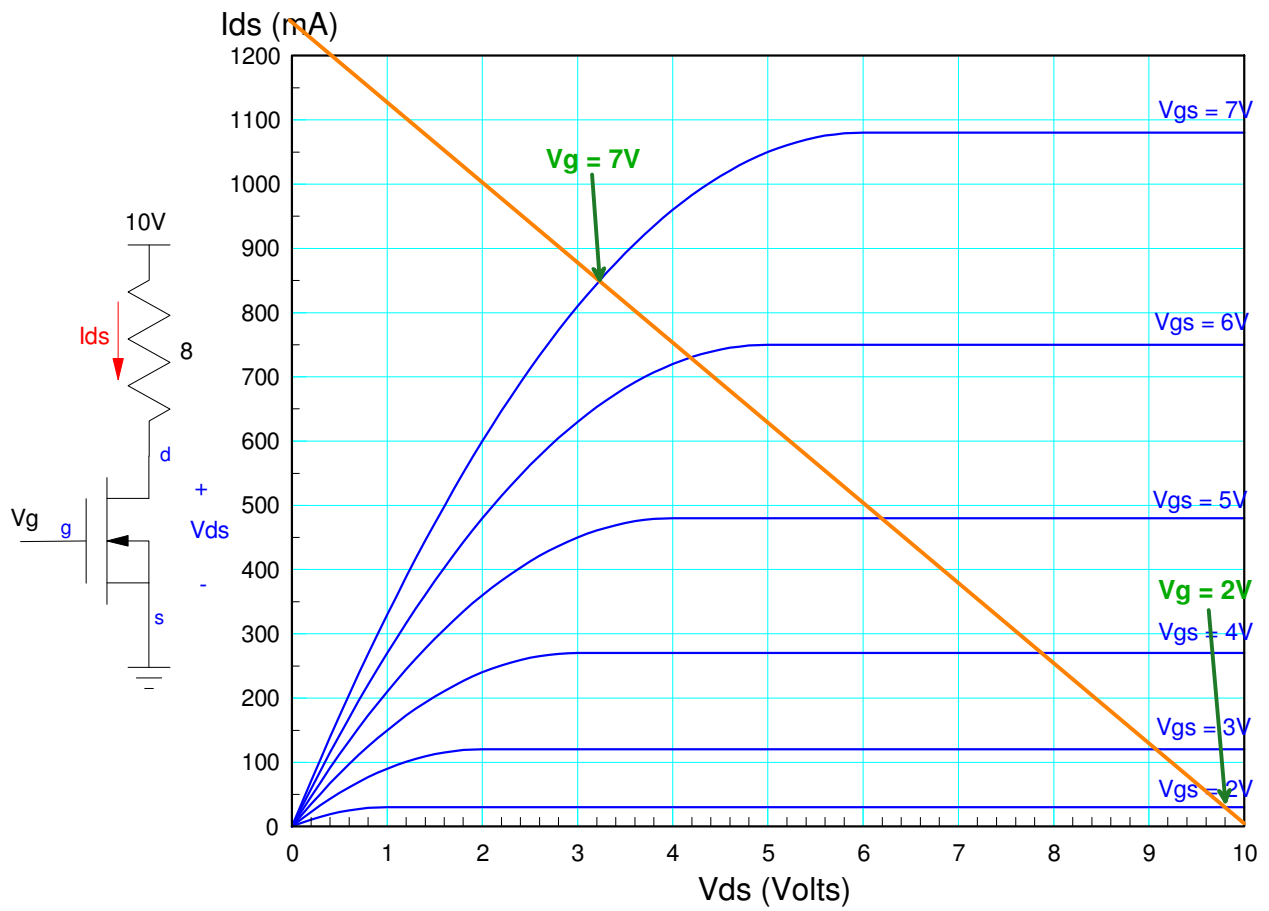
$$1080mA = \frac{k_n}{2} (7V - 1V)^2$$

$$k_n = 0.060 \frac{A}{V^2}$$



9) Draw the load line for the circuit below. From the load line, determine the operating point (V_{ds} , I_{ds}) when

- $V_g = 2V$
- $V_g = 7V$



10) Calculate the operating point (V_{ds} , I_{ds}) when

$V_g = 2V$ (Saturated region)

$$I_{ds} = \frac{k_n}{2}(V_{gs} - V_{th})^2$$

$$I_{ds} = \frac{0.06}{2}(2V - 1V)^2 = 30mA$$

$$V_{ds} = 10 - 8 \cdot I_{ds} = 9.76V$$

$V_g = 7V$ (Ohmic region)

$$I_{ds} = k_n \left(V_{gs} - V_{th} - \frac{V_{ds}}{2} \right) V_{ds}$$

$$I_{ds} = 0.06 \left(7 - 1 - \frac{V_{ds}}{2} \right) V_{ds}$$

$$V_{ds} = 10 - 8 \cdot I_{ds}$$

solving 2 equations for 2 unknowns

$$V_{ds} = 3.218V$$

or

$$V_{ds} = 12.949V$$

The former is the correct solution

ans

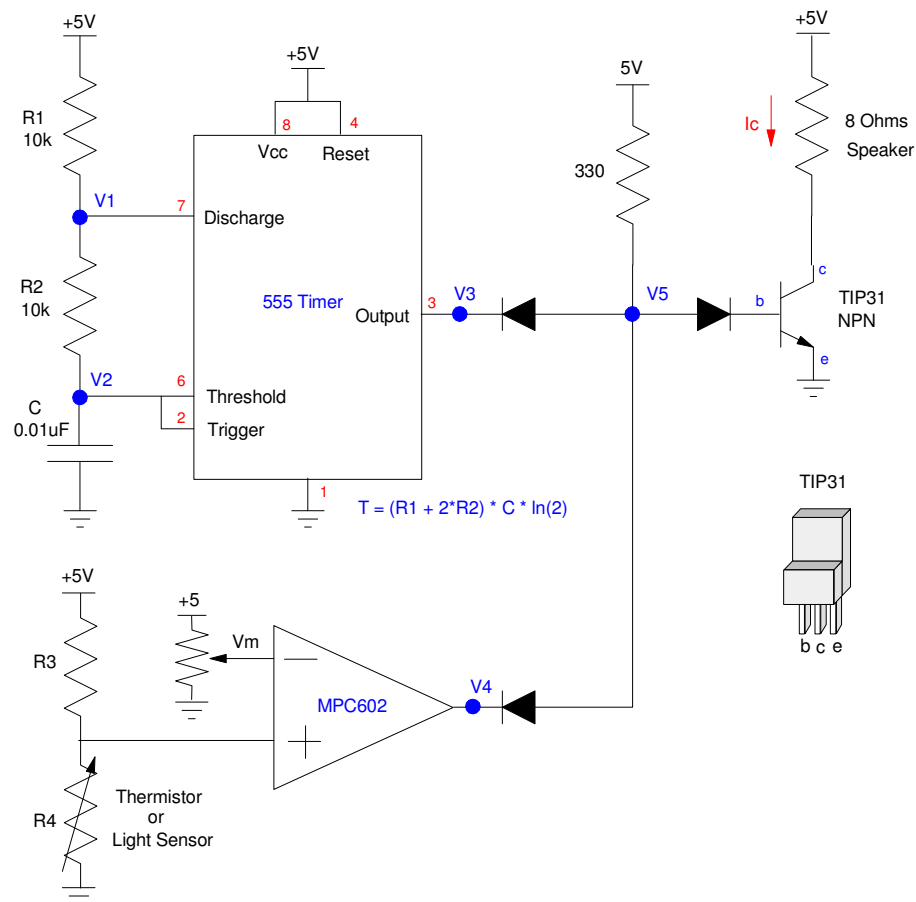
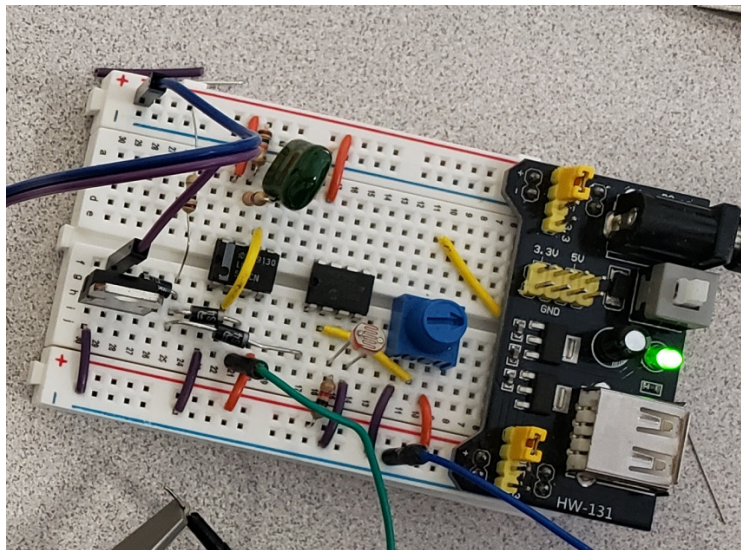
$$\mathbf{V_{ds} = 3.218V}$$

$$\mathbf{I_{ds} = 848mA}$$

Lab: DTL Temperature Alarm

11) Build the following the following circuit with your lab kit

- Include a photo for full credit

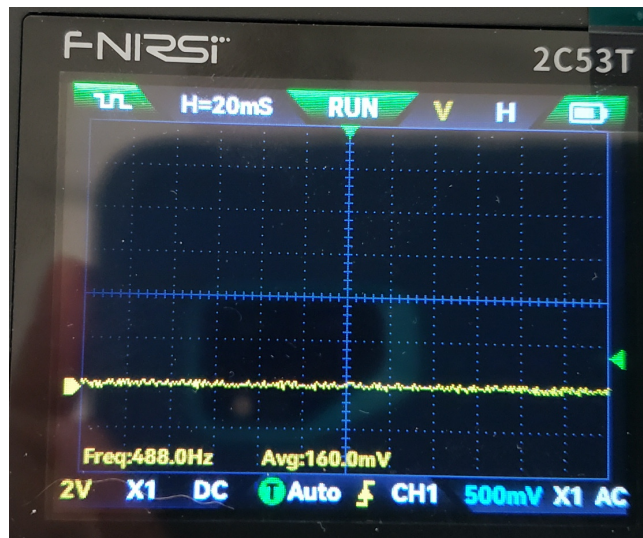


12) Verify your design in hardware (build and test the circuit with your lab kit).

- Alarm is off when it's hot ($R_4 = 100\ \Omega$)
- Alarm is on when it's cold ($R_4 = 10\text{k}\ \Omega$)
- You can also adjust V_m to turn on and off the alarm

Light

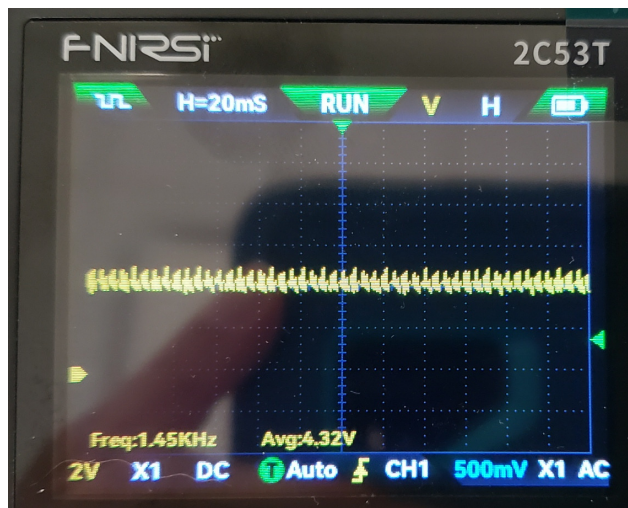
- $V_4 = 160\text{mV}$
- $V_5 = 800\text{mV}$
- Alarm off



Output of comparitor (V4) when light (alarm off)

Dark

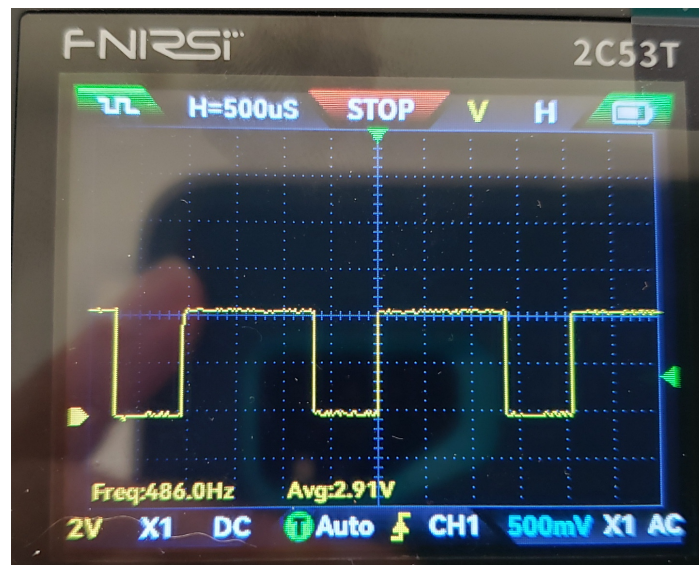
- $V_4 = 4.32\text{V}$
- $V_5 = 1.20\text{V}$
- Alarm On



Output of comparitor (V4) when dark (alarm on)

Alarm On

- V_{ce} = square wave



Ourtput of 555 timer

13) Demonstrate your temperature alarm

- Adjust V_m so that the on/off temperature is close to room temperature
- The alarm should turn off when you blow hot air on the thermistor
- The alarm should go back on when the thermistor cools off

Results:

- Light: Alarm Off
- Dark: Alarm On
- Switches when $V_p = V_m$

Replace the light sensor with a thermistor

- Hot: Alarm Off
- Cold: Alarm On
- Switches when $V_p = V_m$

