

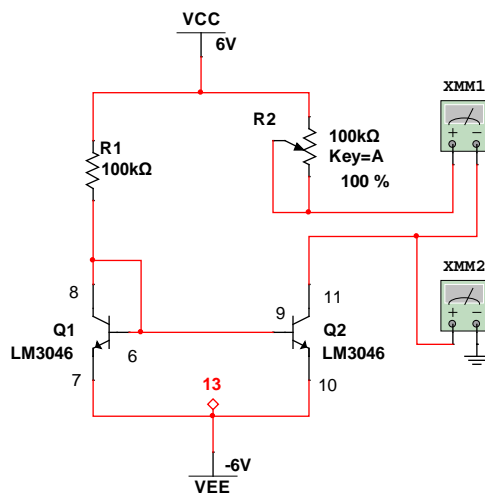
BEE 332 Lab 3
Multi-transistor circuits
Spring 2017

Nicole Hamilton

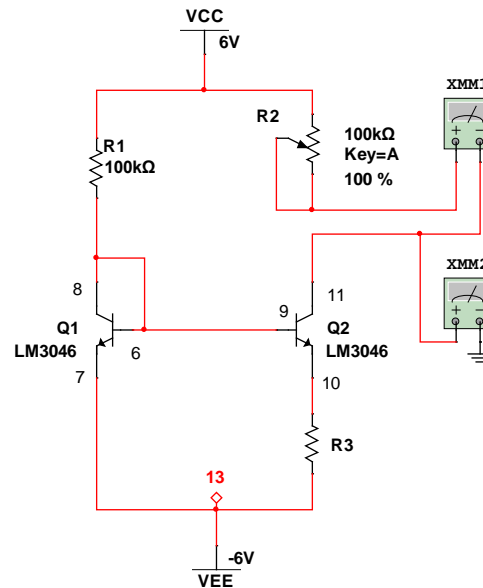
<https://faculty.washington.edu/kd1uj>

Objective

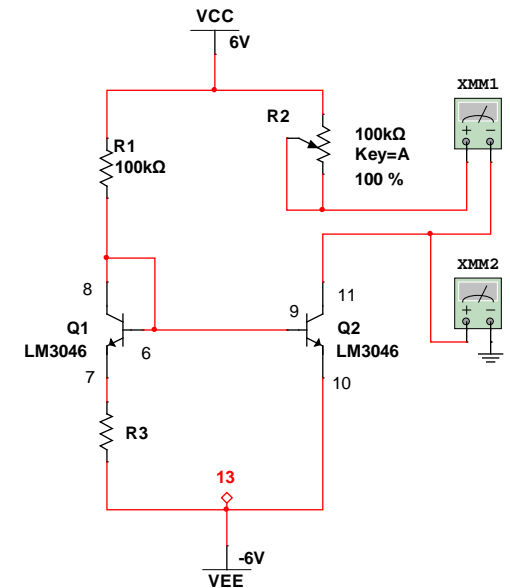
Observe the operating characteristics of several of the most common multi-transistor configurations.



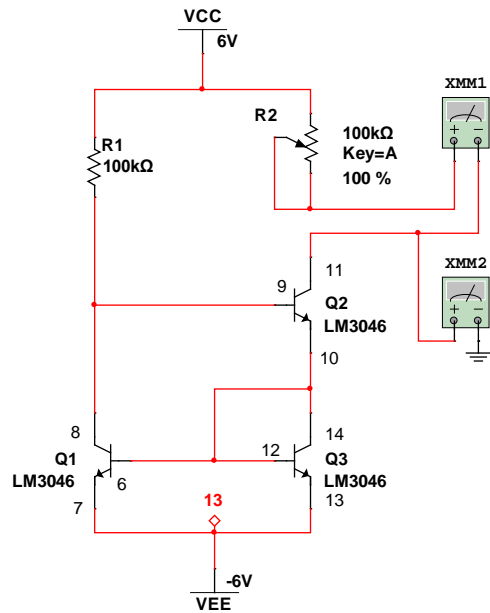
Current mirror



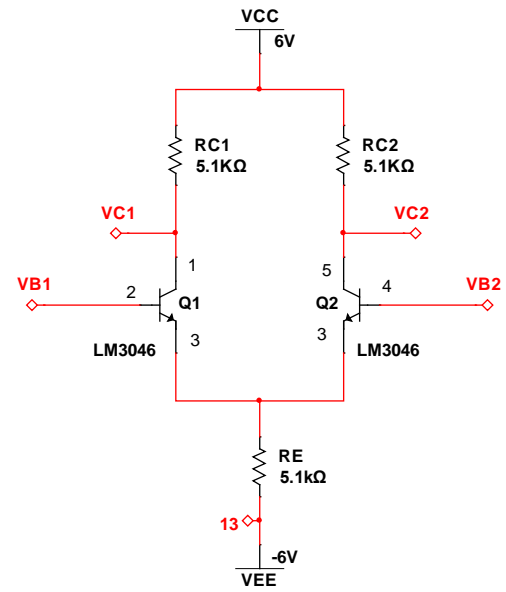
Widlar reducing source



Widlar boosting source



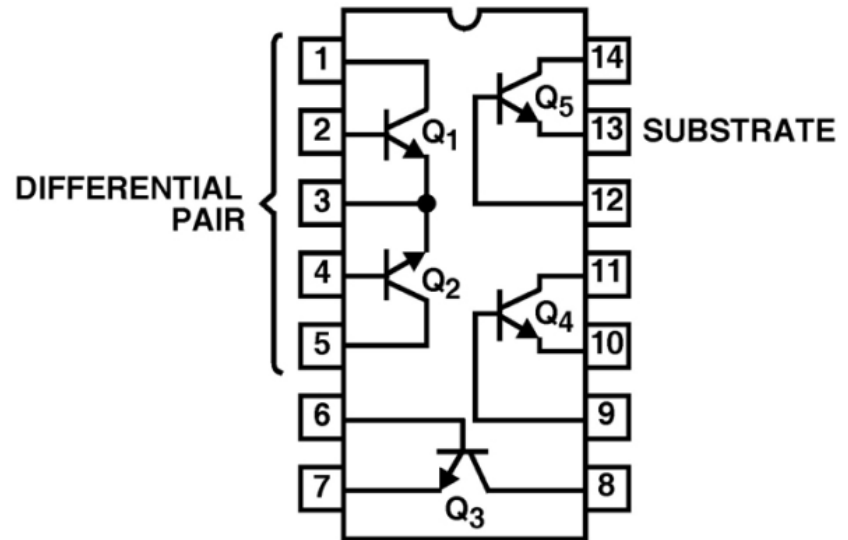
Wilson current source



Differential amplifier

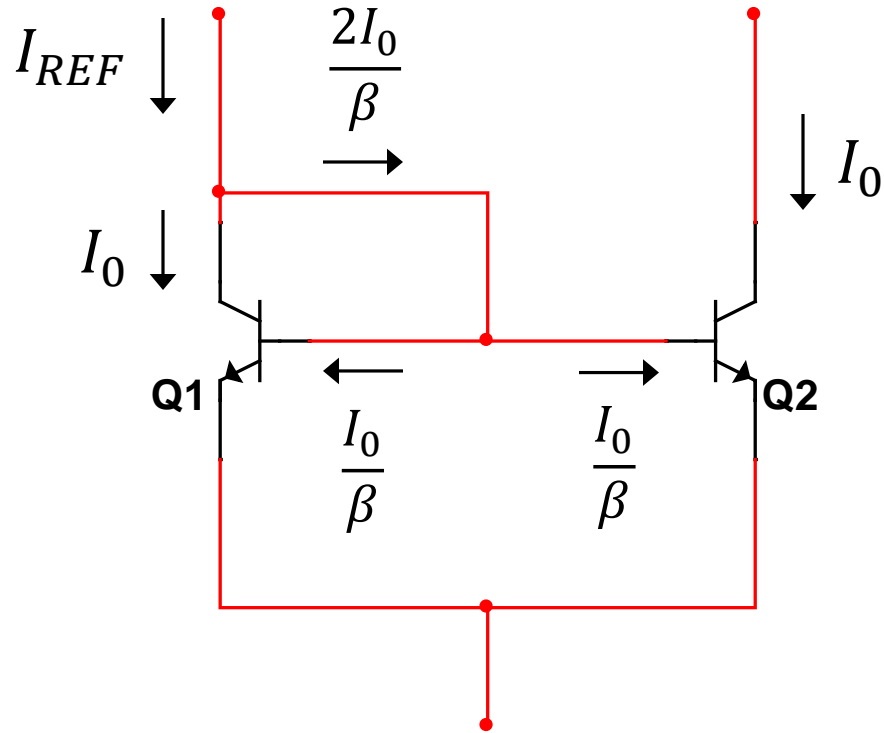
LM3046N package and pinout.

Pinout image source: Intersil CA-3046 datasheet



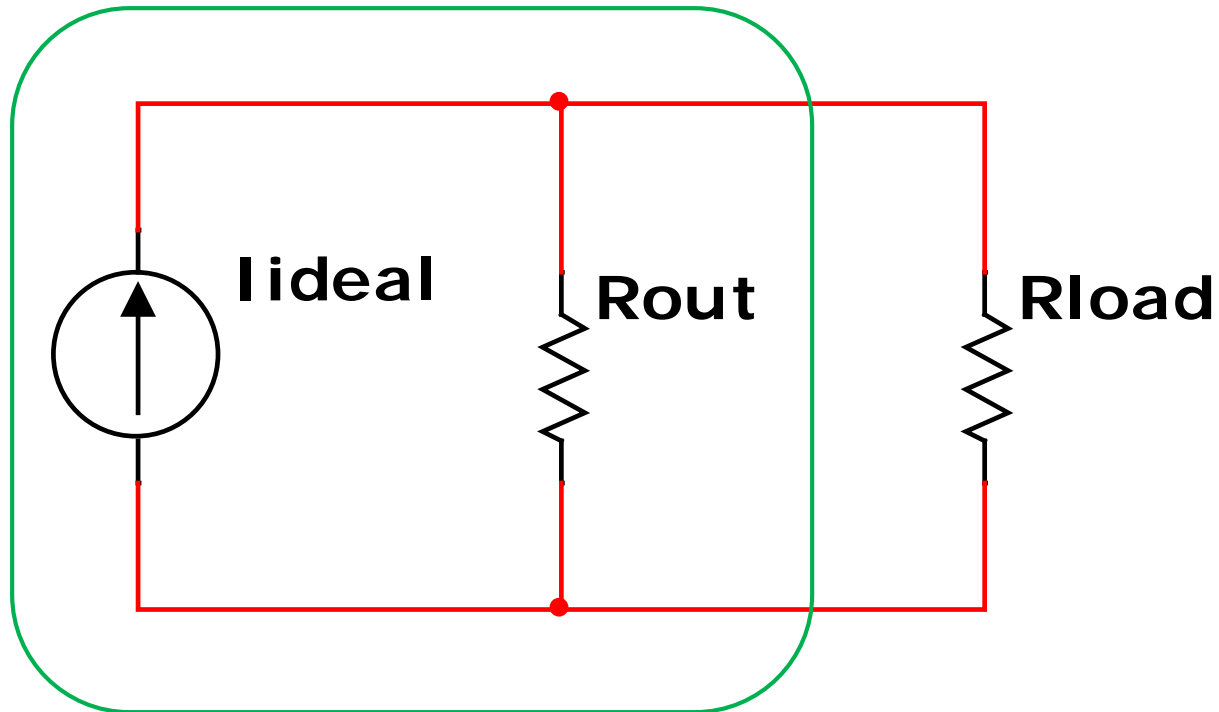
The substrate on pin 13 **MUST** be tied to the lowest potential in the circuit, even if the fifth transistor is not being used.

$$I_C = I_S e^{\frac{V_{BE}}{V_T}}$$

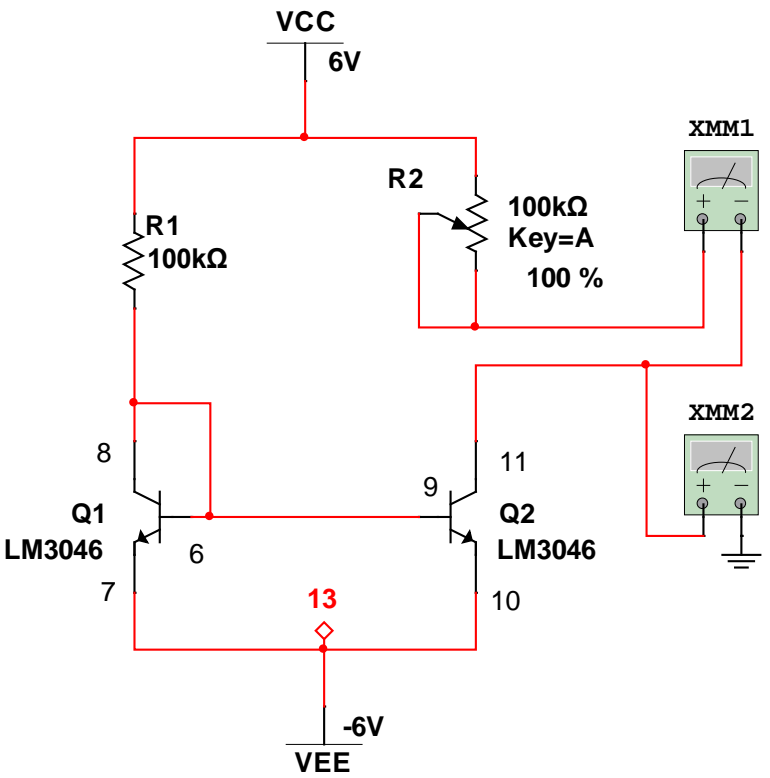


Because the transistors are matched (same silicon) and the $V_{BE1} = V_{BE2}$, the collector currents must be equal.

Non-ideal source



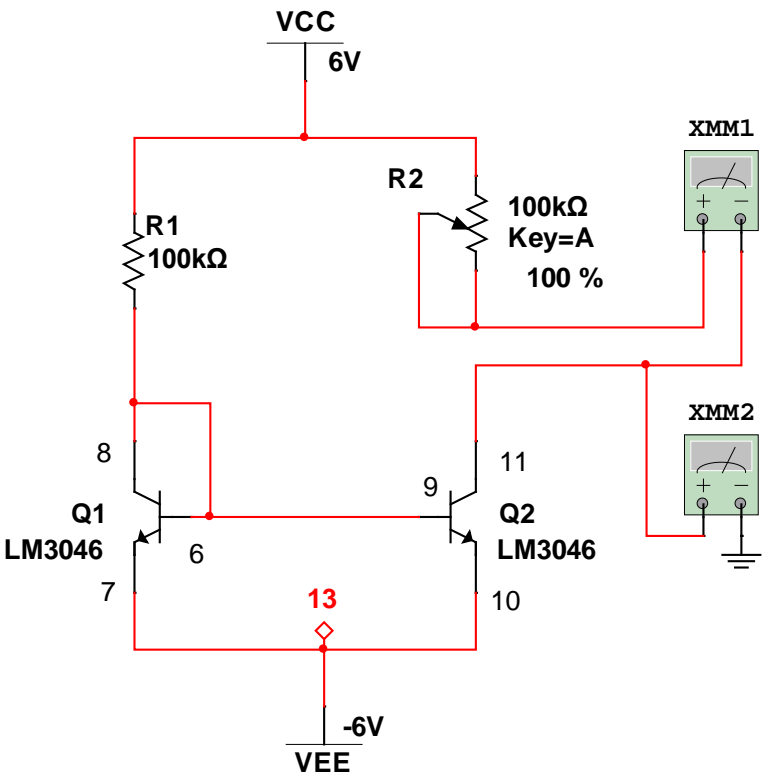
Current mirror



VC2 (V)	IC2 (μA)
6.0	
5.0	
4.0	
:	
-4.0	
-5.0	

Calculate the output resistance of this current source, $R_{out} = \frac{\Delta V}{\Delta I}$.

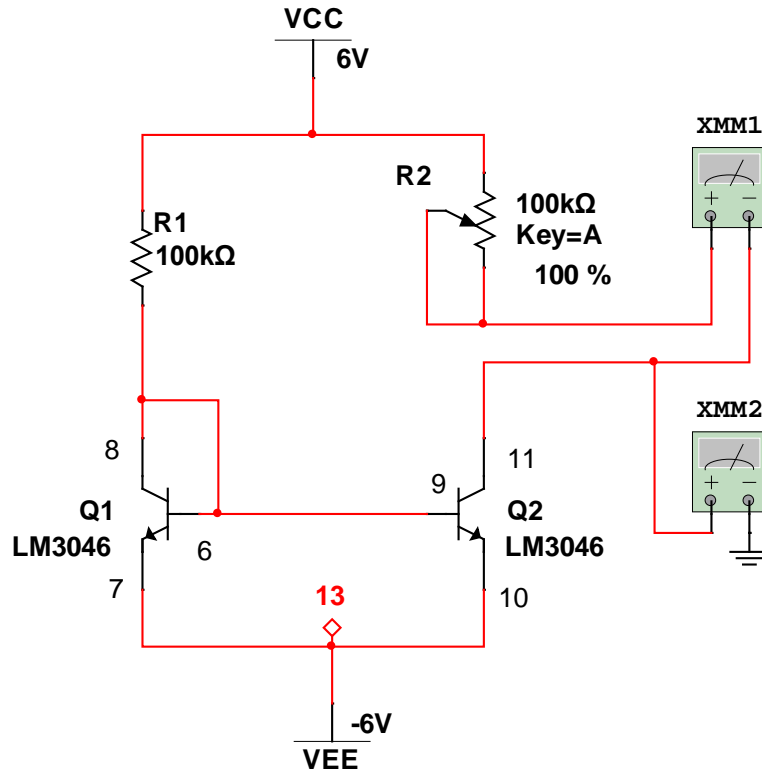
Current mirror



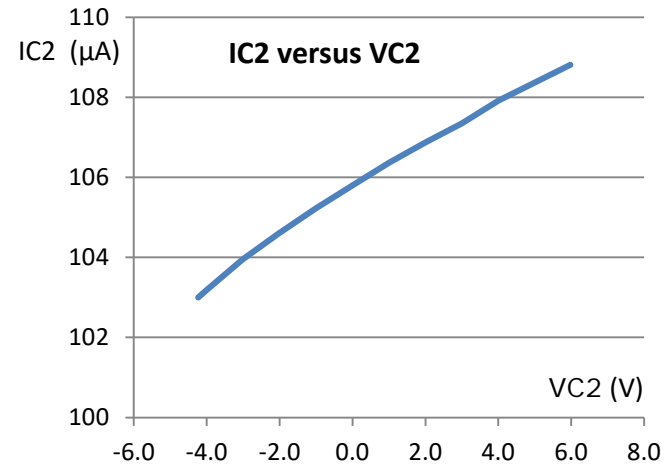
VC2 (V)	IC2 (μA)
6.0	
5.0	
4.0	
:	
-4.0	
-5.0	

Calculate the output resistance of this current source, $R_{out} = \frac{\Delta V}{\Delta I}$.

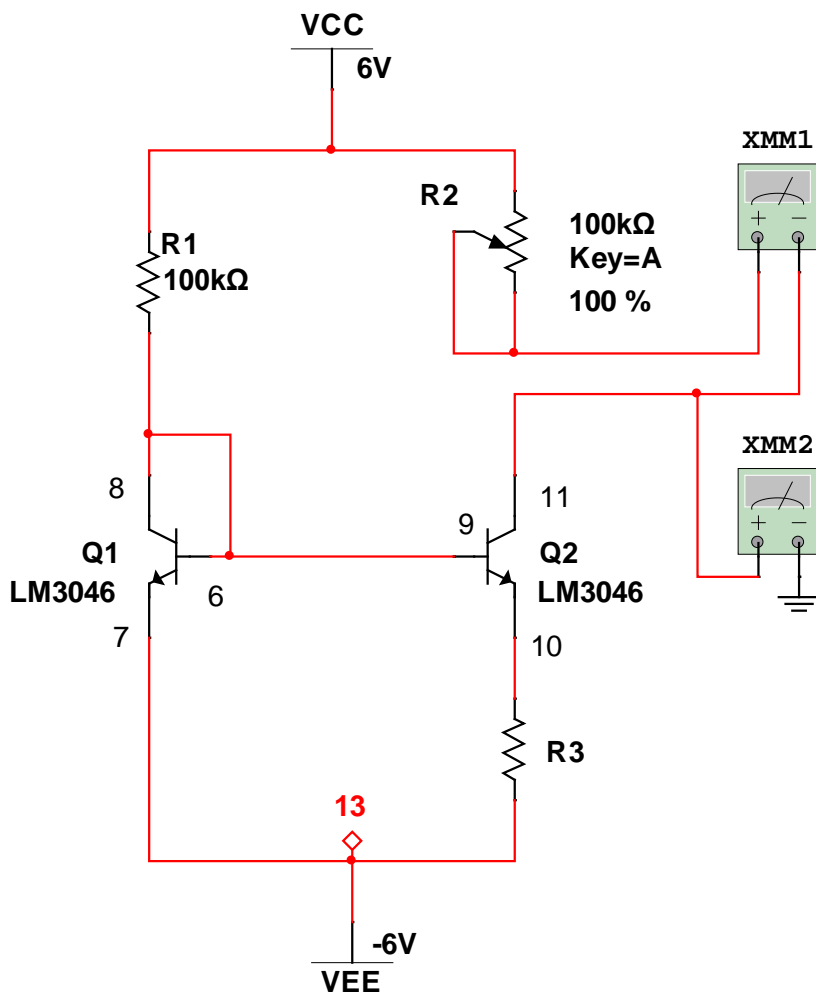
My results



VC2 (V)	IC2 (μA)
5.980	108.81
4.000	107.92
2.998	107.35
2.012	106.88
1.015	106.37
0.024	105.81
-1.015	105.22
-2.009	104.61
-3.012	103.95
-4.010	103.18
-4.230	103.00



Widlar reducing source



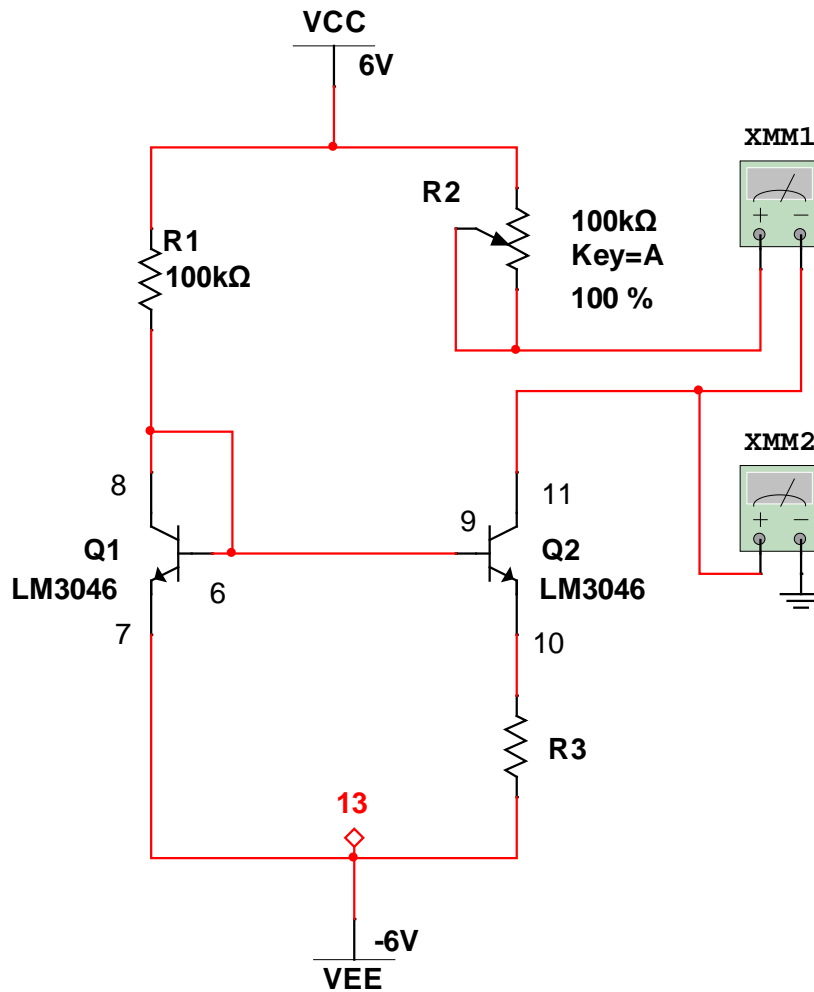
$$R3 = \frac{V_T \ln\left(\frac{IC1}{IC2}\right)}{IC2}$$

VC2 (V)	IC2 (μA)
6.0	
5.9	
5.8	
:	
5.1	
5.0	

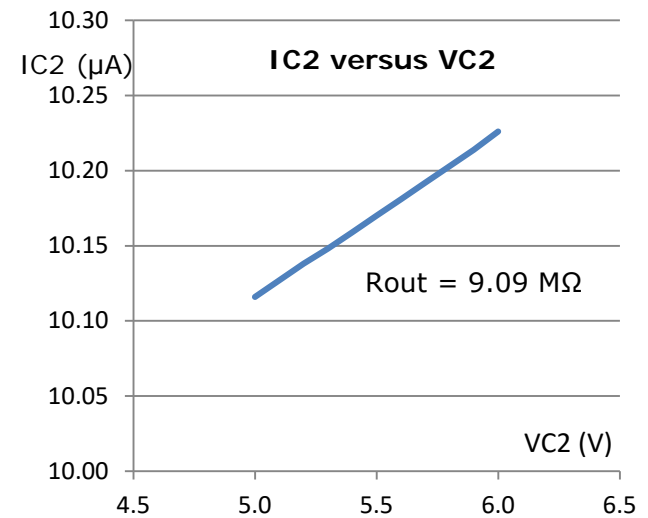
Calculate $R_{out} = \frac{\Delta V}{\Delta I}$.

My results

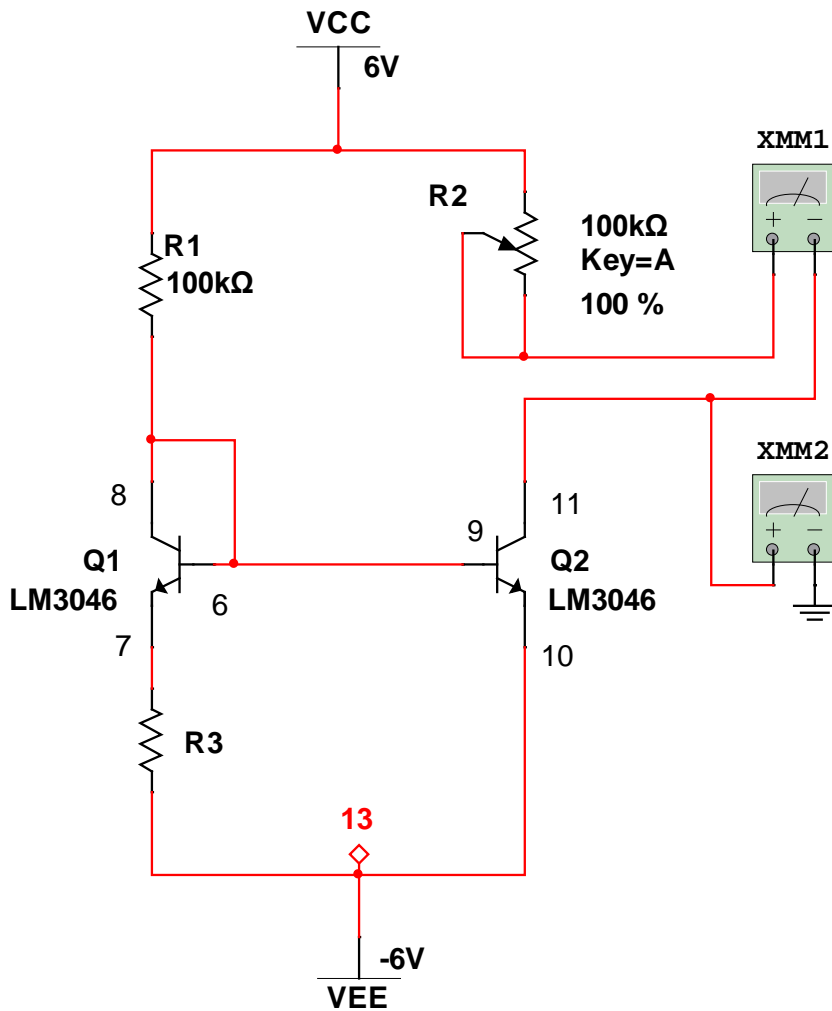
$R3 = 6.68 \text{ K}$



VC2 (V)	IC2 (μA)	VB1 = VC1
5.000	10.116	-5.350
5.100	10.127	-5.350
5.200	10.138	-5.350
5.300	10.148	-5.350
5.400	10.159	-5.350
5.500	10.170	-5.350
5.600	10.181	-5.350
5.700	10.192	-5.350
5.900	10.214	-5.350
6.000	10.226	-5.350



Widlar boosting source



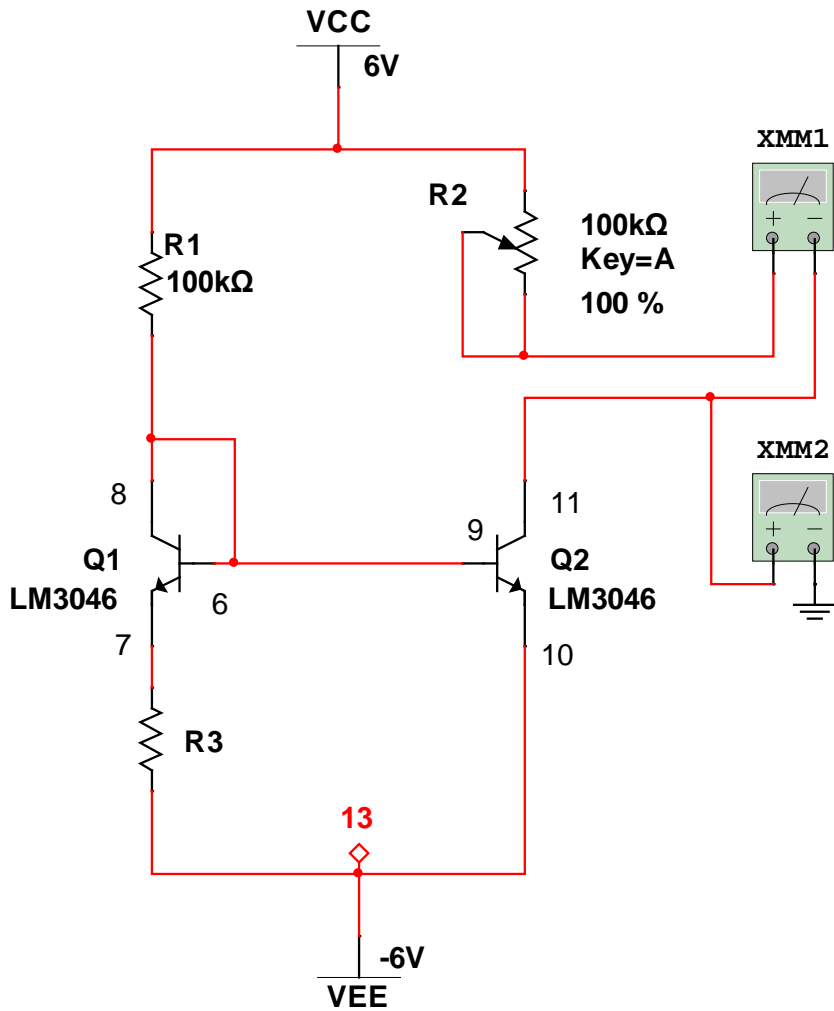
$$R3 = \frac{V_T \ln\left(\frac{IC2}{IC1}\right)}{IC1}$$

VC2 (V)	IC2 (μA)
6.0	
5.0	
4.0	
:	
-4.0	
-5.0	

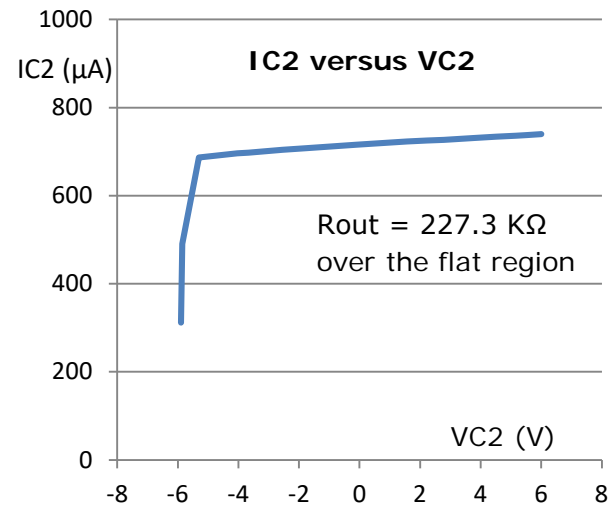
Calculate $R_{out} = \frac{\Delta V}{\Delta I}$.

$$R3 = 469 \Omega$$

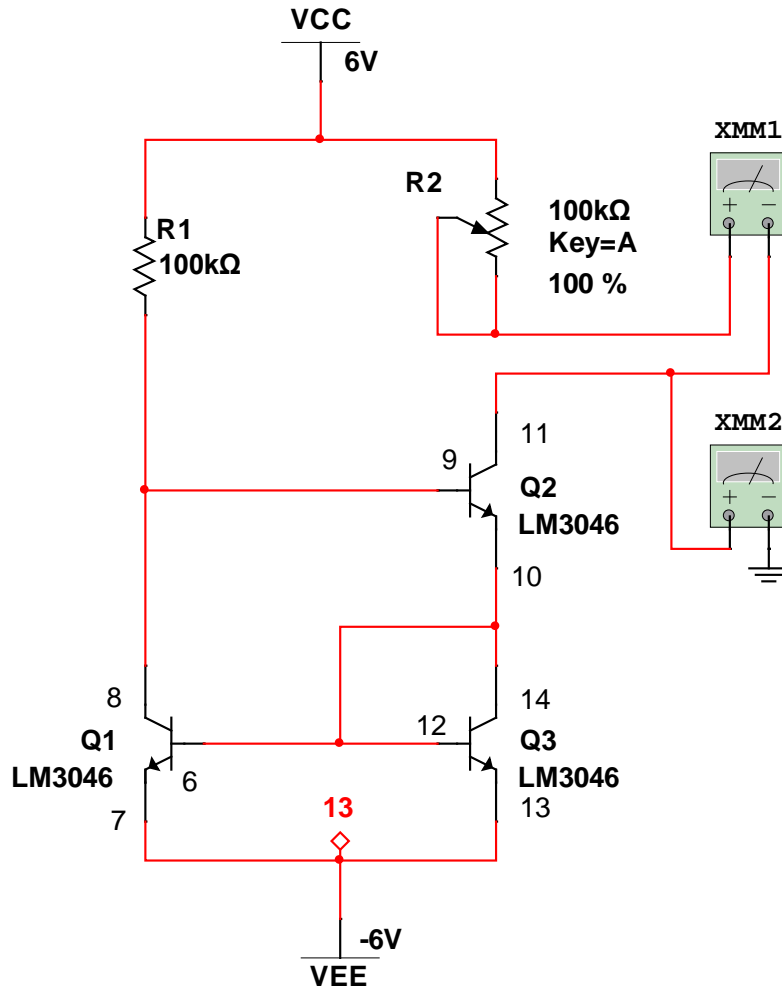
My results



VC2 (V)	IC2 (μA)	VB1 = VC1
6.000	740.000	-5.320
5.530	737.80	-5.320
5.170	736.40	-5.320
4.510	733.74	-5.320
3.810	731.00	-5.320
2.775	726.33	-5.320
2.225	725.44	-5.320
1.564	722.72	-5.320
-0.088	715.48	-5.320
-1.761	707.96	-5.320
-2.546	704.06	-5.320
-3.670	697.90	-5.320
-4.040	695.82	-5.320
-5.300	687.04	-5.320
-5.850	490.42	-5.320
-5.900	311.94	-5.330



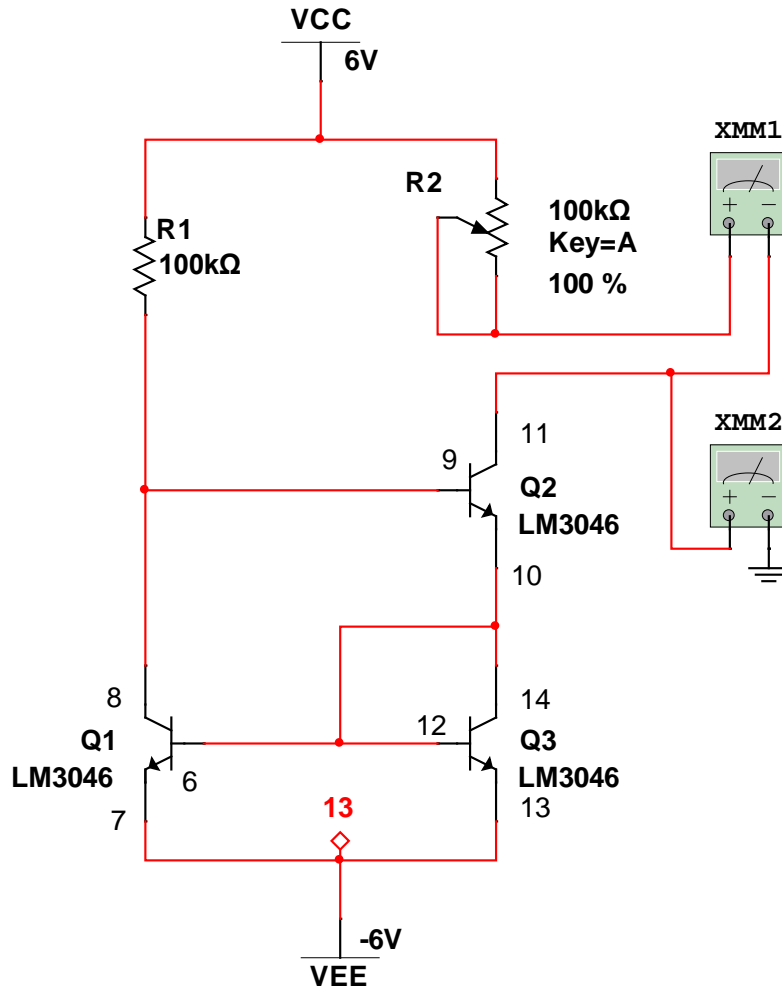
Wilson current source



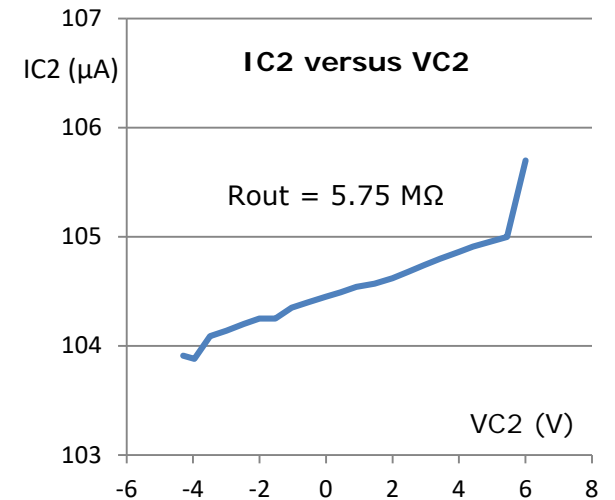
VC2 (V)	IC2 (μA)
6.0	
5.0	
4.0	
:	
-4.0	
-5.0	

Calculate $R_{out} = \frac{\Delta V}{\Delta I}$.

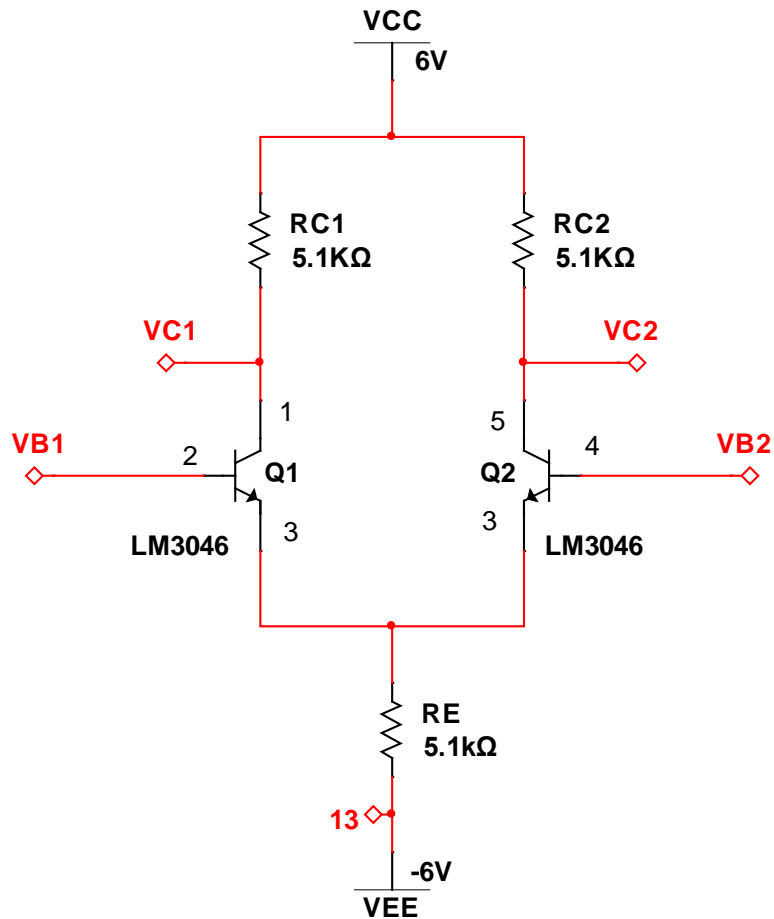
My results



VC2 (V)	IC2 (μA)	VB1	VC1
6.00	105.70	-4.55	-4.03
5.44	105.00	-4.52	-4.01
5.00	104.96	-4.52	-4.03
4.42	104.91	-4.53	-4.00
3.99	104.86	-4.52	-4.03
3.43	104.80	-4.52	-4.03
2.95	104.74	-4.52	-4.02
2.47	104.68	-4.52	-4.02
2.00	104.62	-4.51	-3.99
1.46	104.57	-4.51	-4.02
0.91	104.54	-4.52	-4.02
0.44	104.49	4.52	-4.01
-0.02	104.45	-4.50	-4.04
-0.54	104.40	-4.51	-4.03
-1.03	104.35	-4.51	-4.03
-1.52	104.25	-4.50	-3.92
-2.01	104.25	-4.50	-3.87
-2.48	104.20	-4.51	-3.45
-3.00	104.14	-4.51	-4.01
-3.49	104.09	-4.51	-4.01
-3.960	103.88	-4.5	-3.02
-4.300	103.91	-4.5	-2.91



Differential amplifier



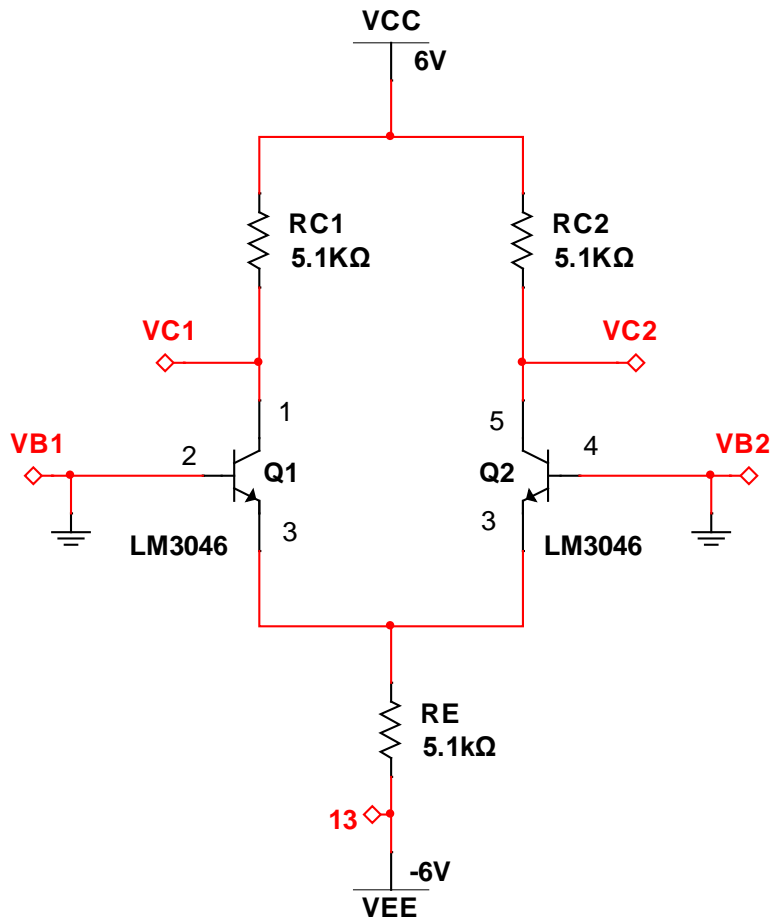
Amplifies the *difference* between VB1 and VB2.

The difference is called the *differential-mode signal*.

The average of the two signals is called the *common-mode signal*.

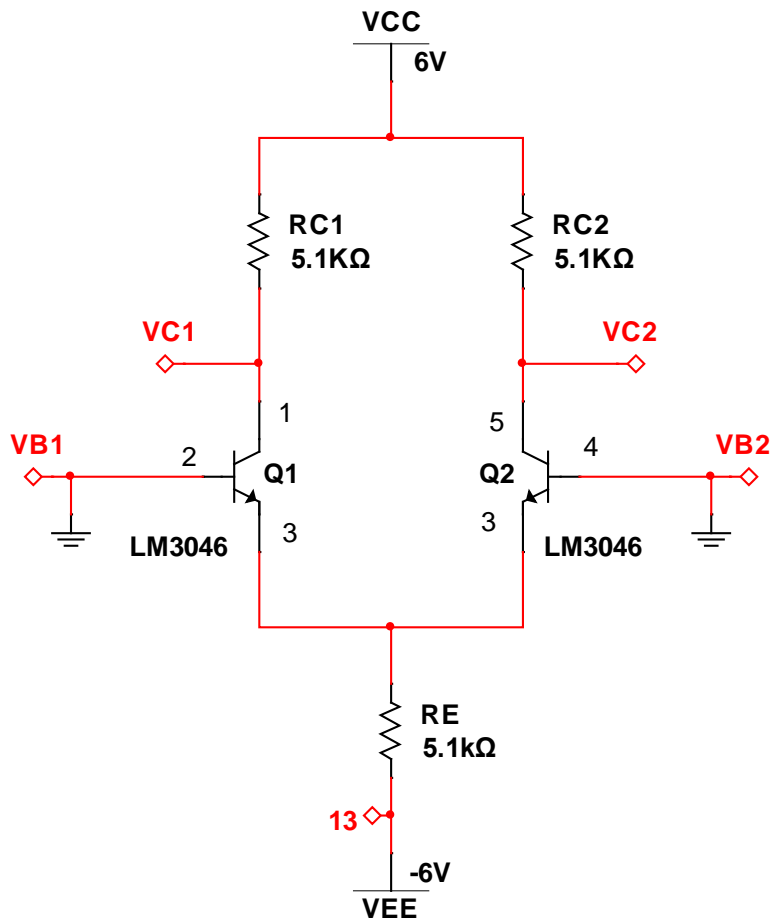
The *common-mode rejection ratio (CMRR)* is the differential-mode gain divided by the common-mode gain.

Grounded inputs



Verify both Q1 and Q2 are in the forward active region.

My results



With both VB1 and VB2 grounded:

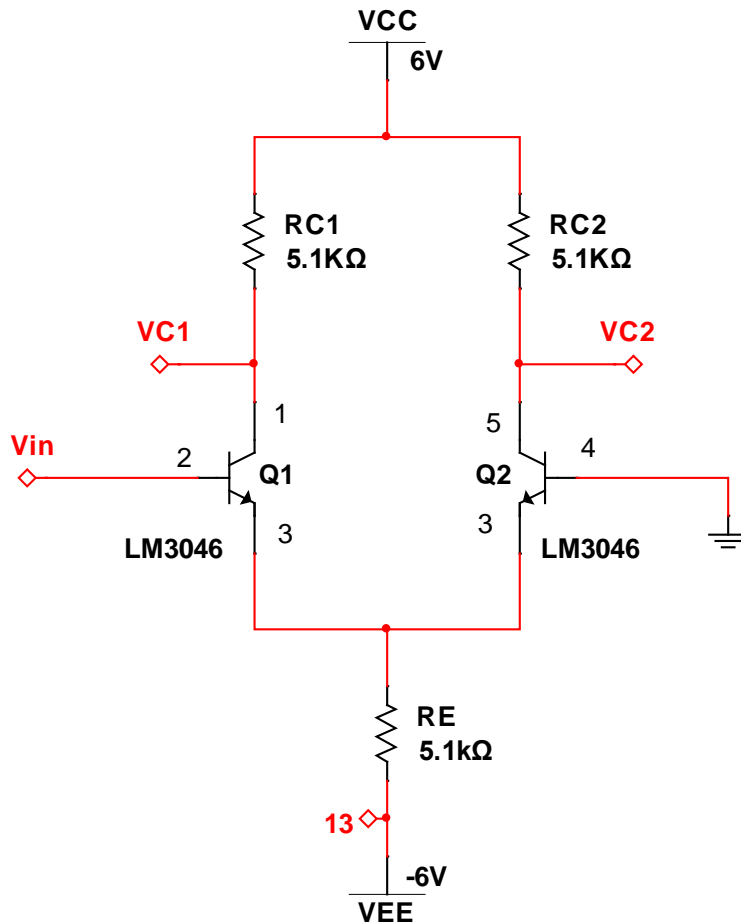
$$VC1 = VC2 = 3.363 \text{ V}$$

$$VB1 = VB2 = 0$$

$$VE1 = VE2 = -0.70635 \text{ V}$$

Both BE junctions are forward-biased and both BC junctions are reversed-biased, so both Q1 and Q2 are indeed in the FA region.

Differential mode



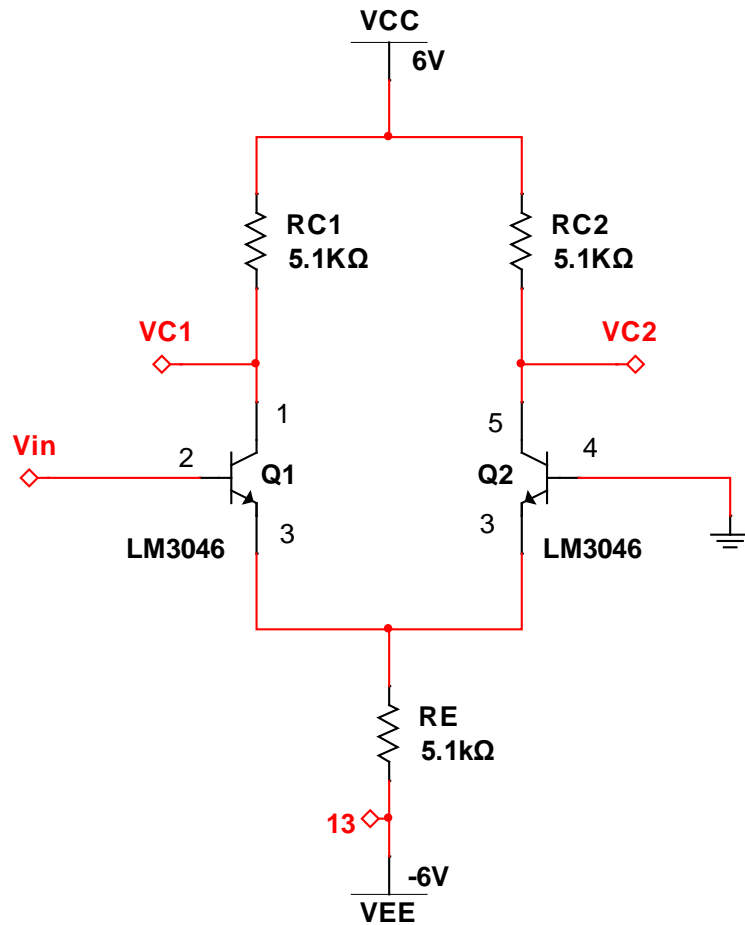
Set $V_{in} = 100 \text{ mVpp}$ 1 KHz sine wave, 0 V DC offset.

Capture screenshots of both VC1 and VC2.

Calculate differential mode gain, A_v , in each case.

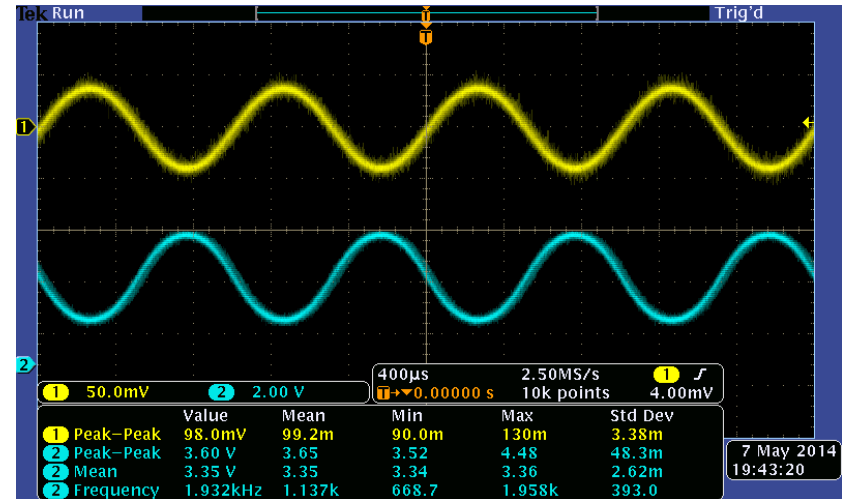
Increase frequency until A_v has fallen by 3 dB.

My results

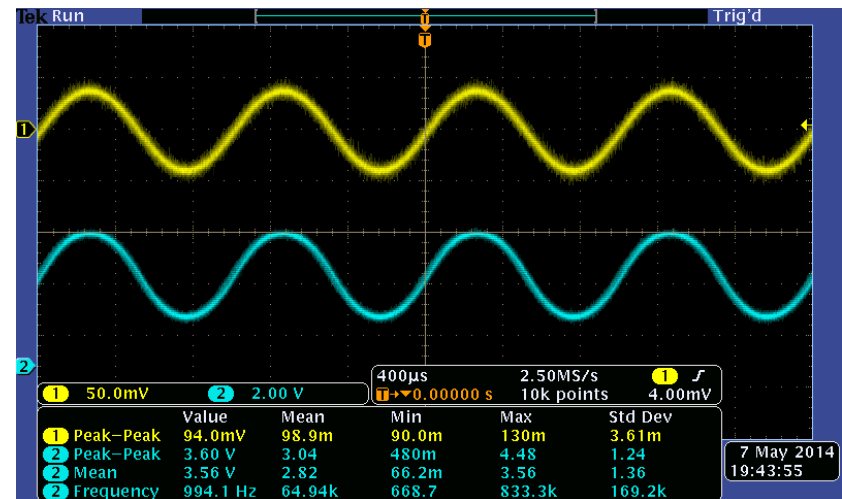


Set $V_{in} = 100 \text{ mVpp}$ 1 KHz sine wave, 0 V DC offset.

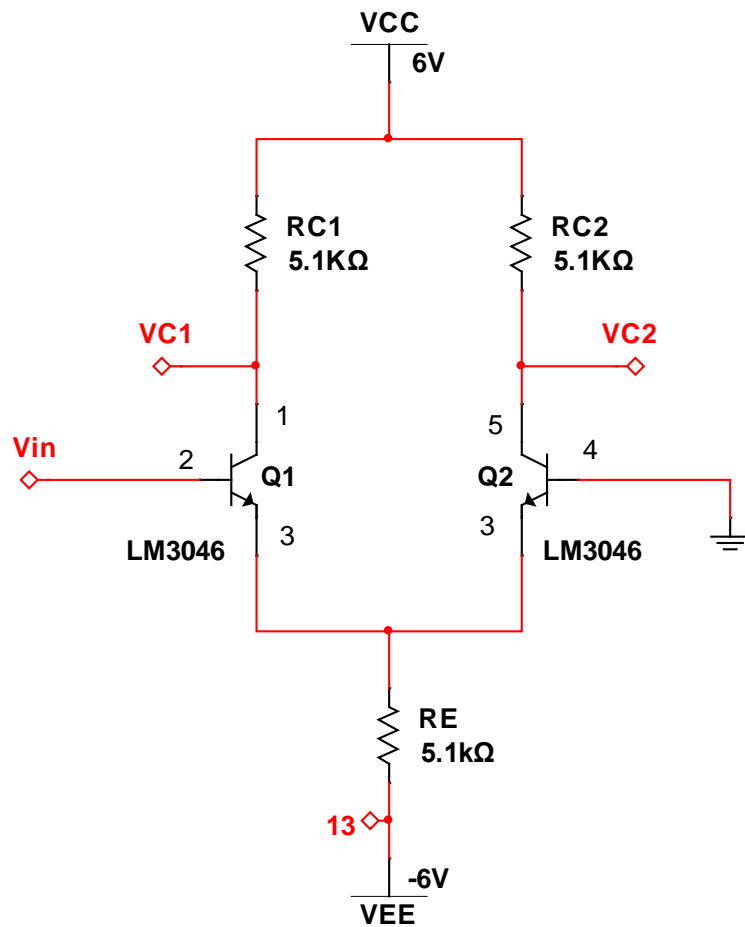
$VC1, A_{v1} = -36.7$



$VC2, A_{v1} = 38.3$

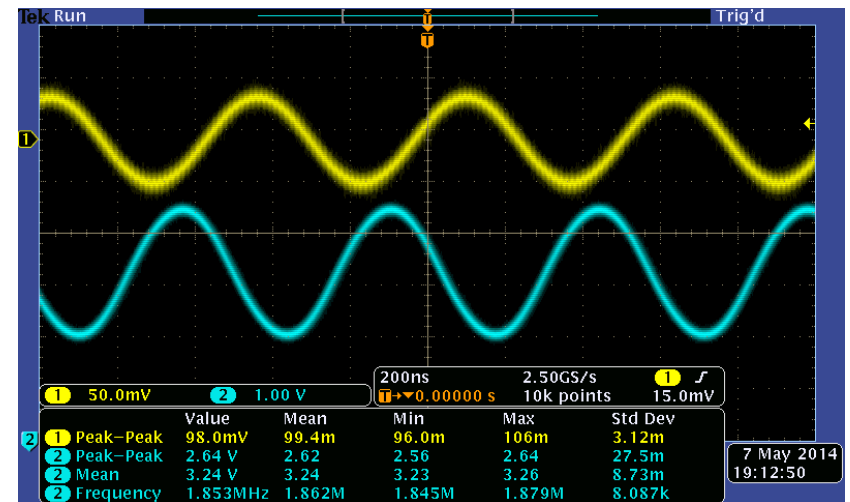


My results

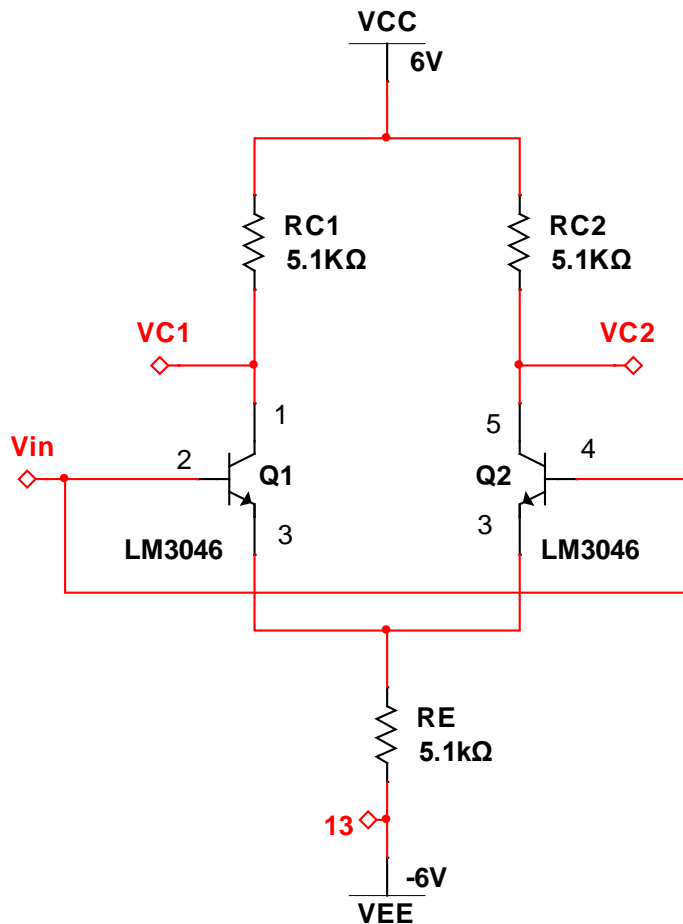


3 db point is where A_v drops to
 $.7071 * A_v$ at 1 KHz.

VC1, $A_{v1} = -36.7$



Common mode



Set $V_{in} = 3$ Vpp 1 KHz sine wave, 0 V DC offset.

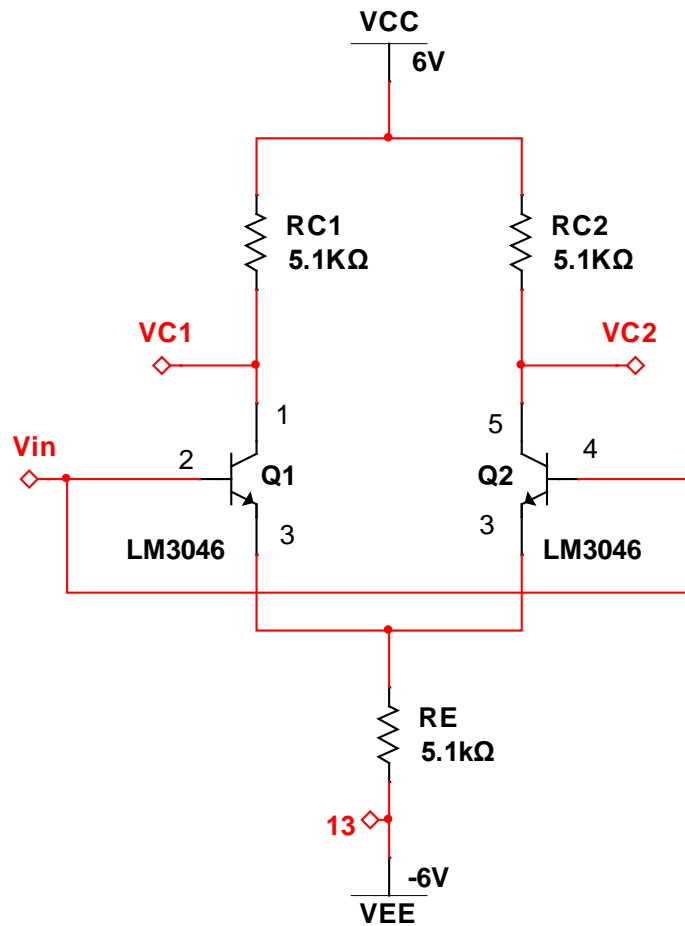
Capture screenshots of both VC1 and VC2.

Calculate common mode gain, A_v , in each case.

Increase frequency until A_v has fallen by 3 dB.

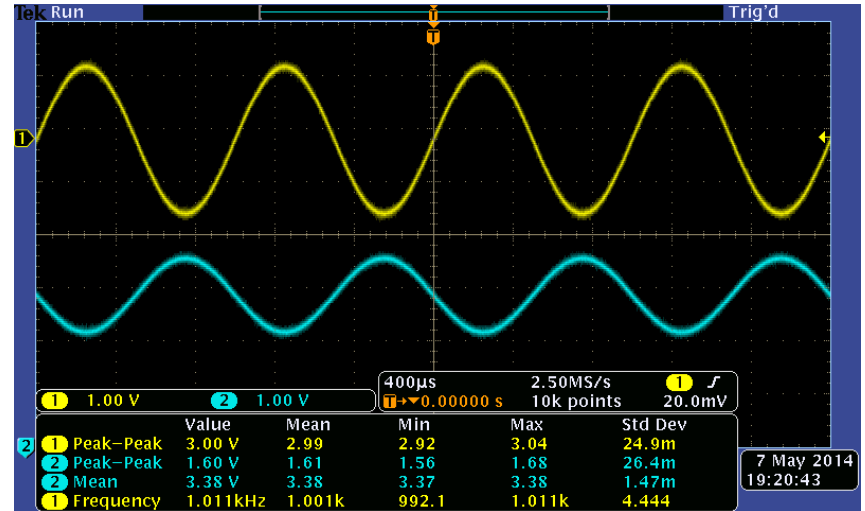
Repeat with $V_{in} = 200$ mVpp, 1 KHz sine wave, DC offset = +4.9V.

My results

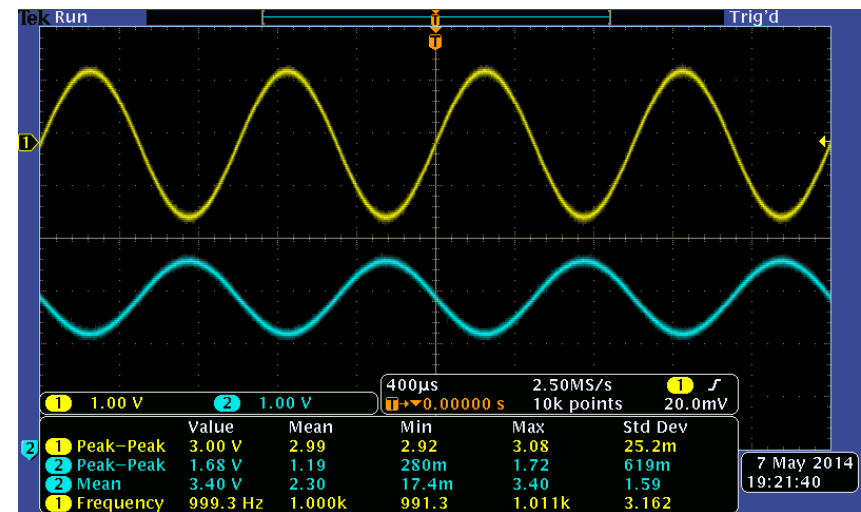


Set $V_{in} = 3$ Vpp 1 KHz sine wave, 0 V DC offset.

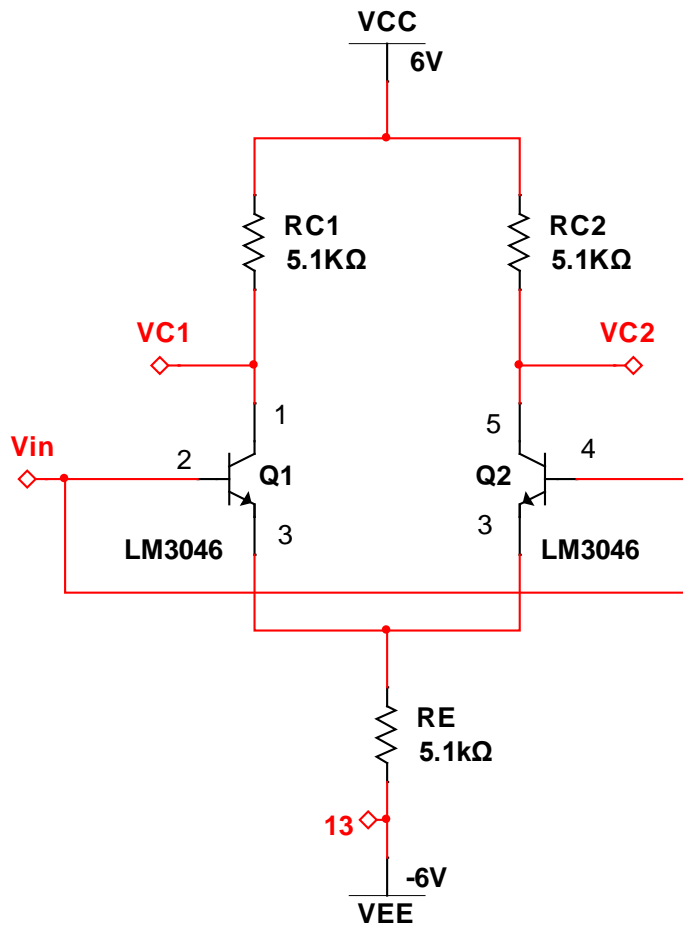
VC1, $A_{v1} = -0.54$



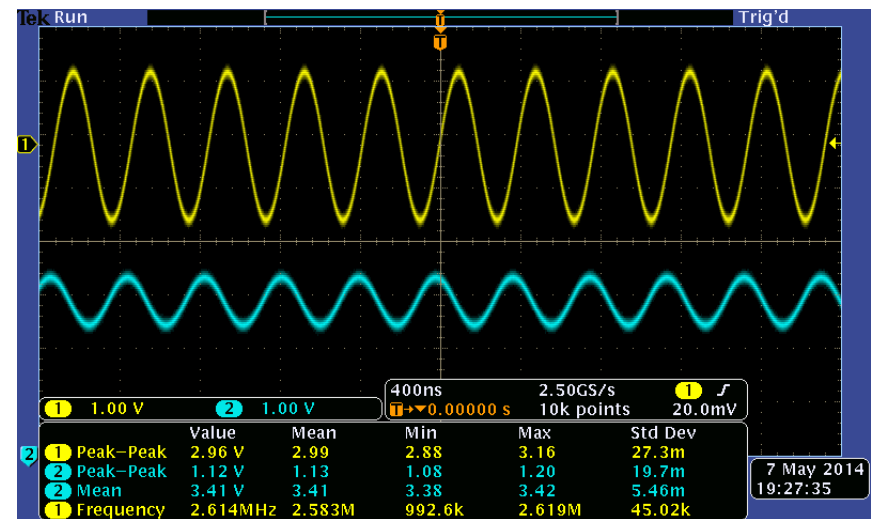
VC2, $A_{v2} = -0.40$



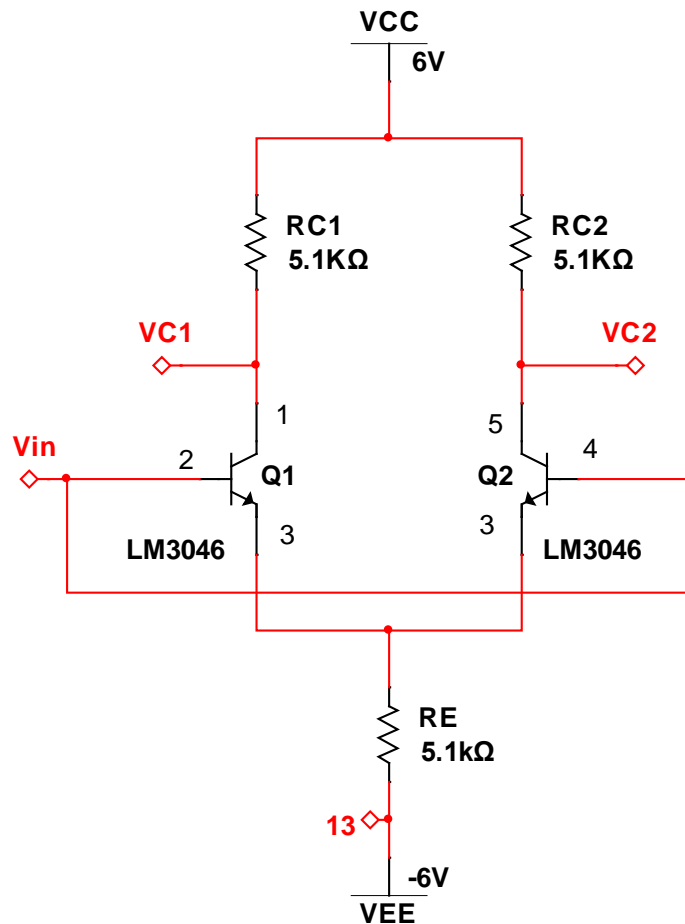
My results



3 dB point at 2.6 MHz.

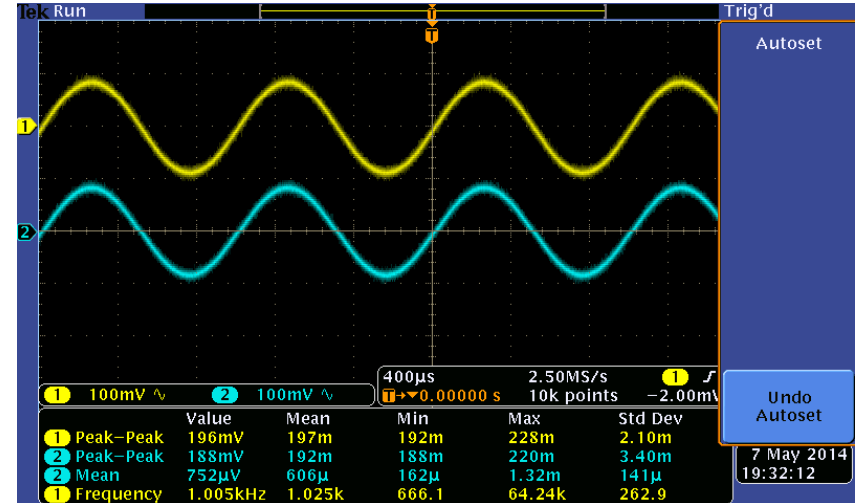


My results



Set $V_{in} = 200 \text{ mV}_{pp}$, 1.0 KHz sine wave, DC offset = +4.9V.

AC-coupled, $A_v = 0.97$



DC coupled, DC offset = 3.95 V.

