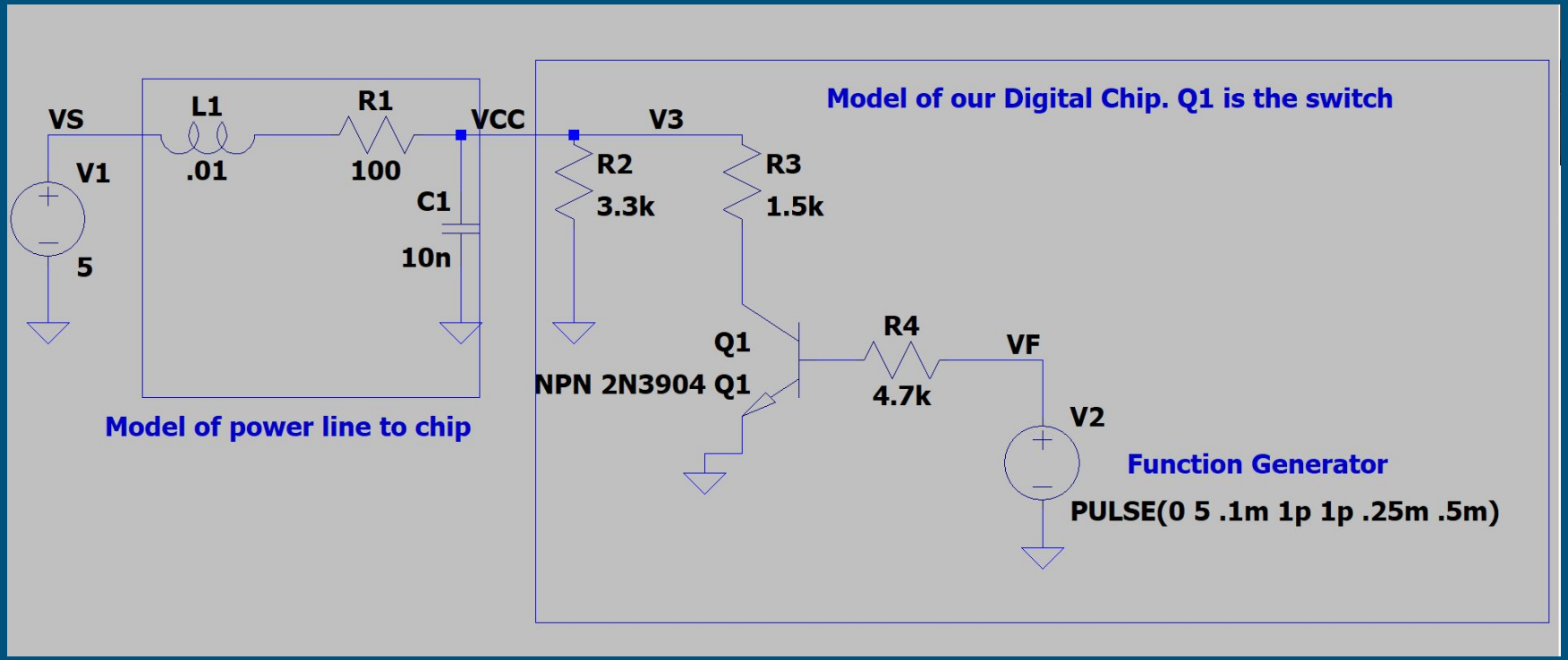
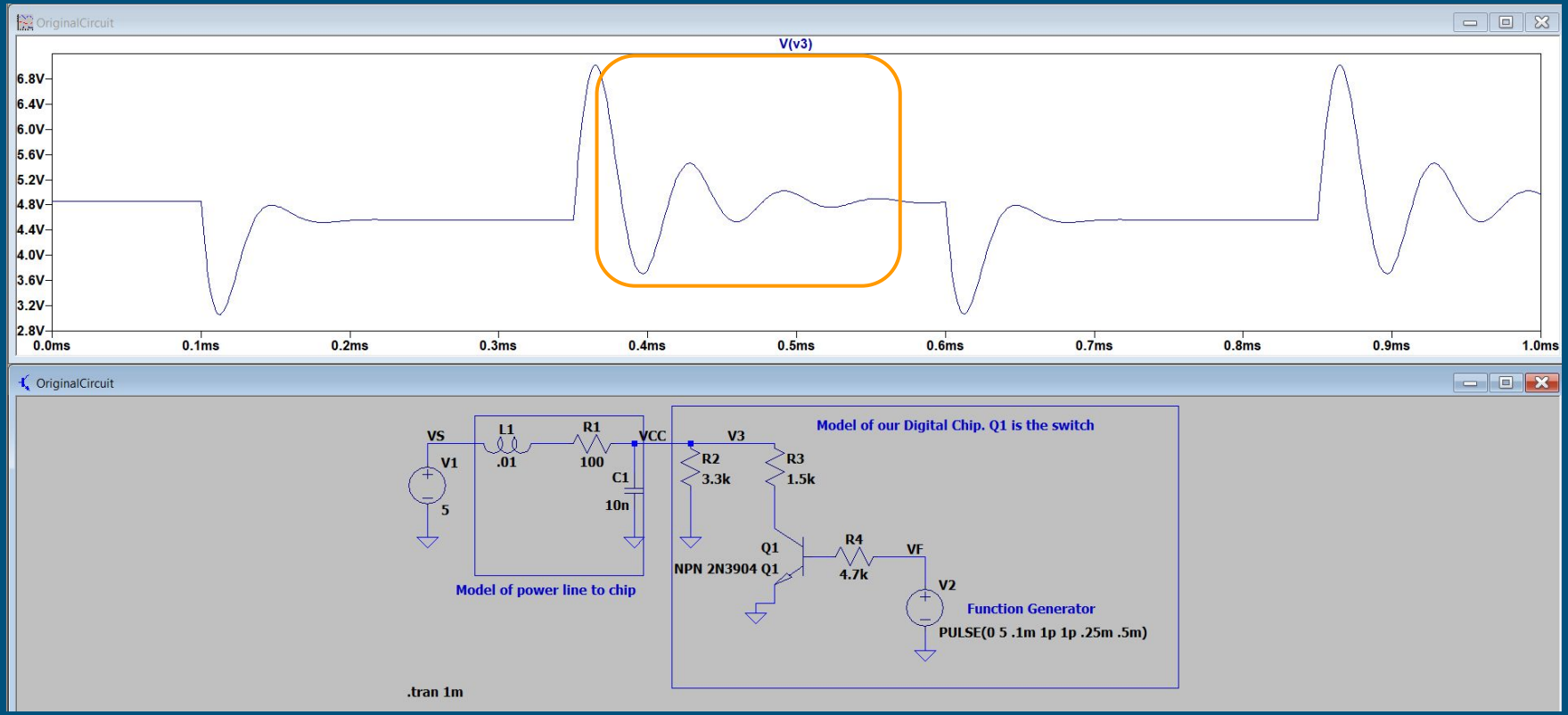
Surge Suppressor Project
Group 1

Madison Klementyn, Jasmine Koski,
Risto Rushford
July 22, 2020

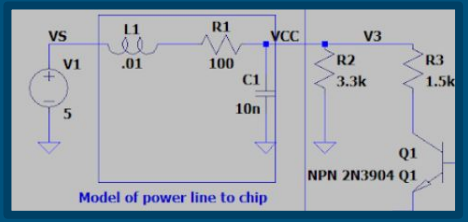
Original Circuit



Noisy Circuit



Hand Calculations - Original Circuit Transfer Function H(s)



$$\frac{\left(\frac{1}{sC}\right)}{sL + R1 + \left(\frac{1}{sC}\right)}$$

Hand Calculations - Original Circuit Transfer Function H(s)

$$H(s) = \left. \frac{\frac{1}{s10\text{E}{-9}}}{\frac{1}{s10\text{E}{-9}} + s0.10 + 100} \right|_{s}$$

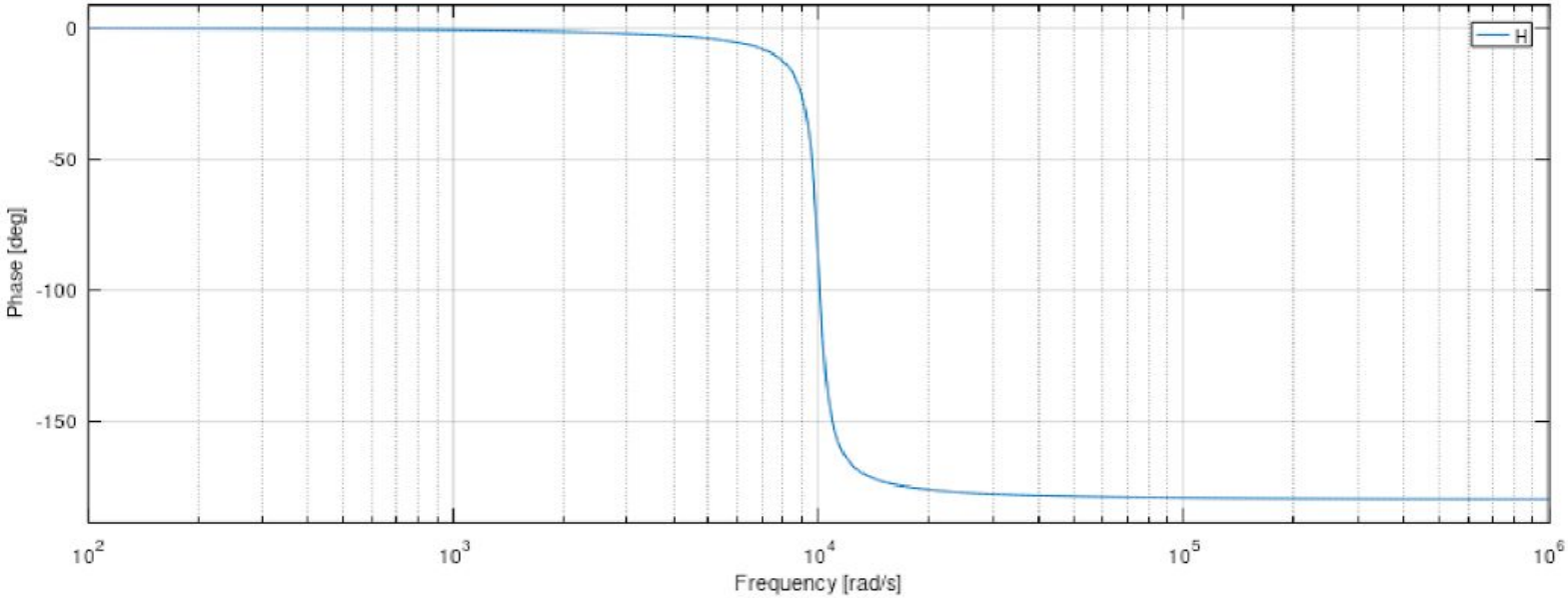
$$H(j\omega) = \left. \frac{\frac{1}{j\omega 10\text{E}{-9}}}{\frac{1}{j\omega 10\text{E}{-9}} + j\omega 0.10 + 100} \right|_{s=(j\omega)}$$

$$\omega = 2\pi f$$

$$\omega = 2\pi \; 2kHz$$

$$\omega = 12566 \; \frac{rad}{s}$$

Hand Calculations - Original Circuit Bode & Phase Plots



Hand Calculations - Original Circuit Transfer Function H(s)

$$H(j12566) = \left. \frac{\frac{1}{j12566 \cdot 10\text{E}{-9}}}{\frac{1}{(j12566) \cdot 10\text{E}{-9}} + (j12566 \cdot 0.10) + 100} \right|_{s=(j12566)}$$

$$H(j12566) = 1.184019 - j17.71648$$

$$H(j12566) = 1.18\angle -0.855°$$

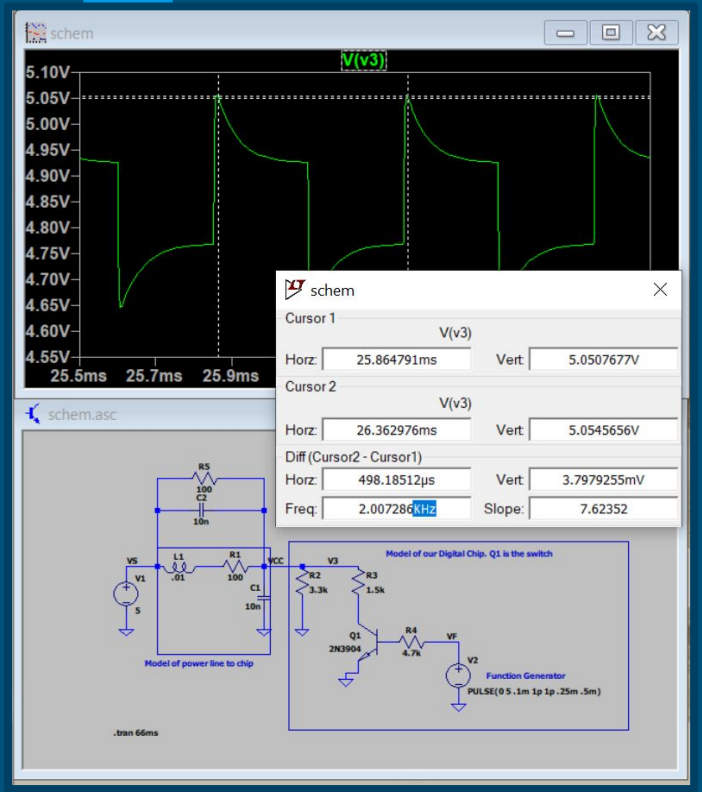
Hand Calculations - Original Circuit Vout

$$v_o(t) = A|H(j\omega)|cos(\omega t - \theta(\omega)$$

$$v_o(t) = (5)|(1.18)|cos(12566t - (-0.855°))$$

$$v_o(t) = 5.9 \cdot cos(12566t + 0.855°)V$$

Hand Calculations - “The Fix”
Transfer Function H(s)



$$\frac{\left(\frac{1}{\left(s10E-9+\frac{1}{3300}+\frac{1}{1500}\right)}\right)}{\left(\frac{1}{\left(s10E-9+\frac{1}{3300}+\frac{1}{1500}\right)}\right)+\left(\frac{1}{s10E-9+\left(\frac{1}{100}\right)+\left(\frac{1}{S0.10+100}\right)}\right)}$$

https://rb.gy/miyhyh

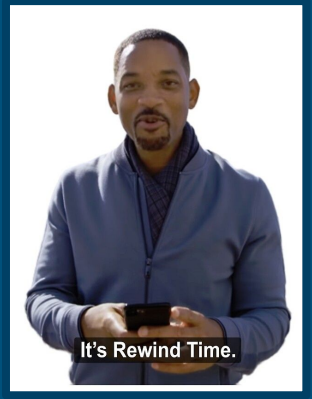
$$\omega = 2\pi f$$

$$\omega = 2\pi\ 2kHz$$

$$\omega = 12566\ \frac{rad}{s}$$

Hand Calculations - “The Fix” Transfer Function H(s)

$$= \frac{0.00000001s + \frac{0.1s + 200}{10s + 10000}}{0.00000001s + \frac{1.0E-15s^3 + 1.09797E-9s^2 + 2.09697E-6s + \frac{0.0000000001s^3 + 0.0001s^2 + 0.42929s + 419.39393}{0.1s + 100}}{0.0000001s^2 + 0.0001s + \frac{0.01s^2 + 30s + 20000}{0.1s + 100}}}$$



Hand Calculations - “The Fix” Transfer Function H(s)

$$H(s) = \frac{\left(\frac{1}{\left(s10E{-}9{+}\frac{1}{3300}{+}\frac{1}{1500}\right)}\right)}{\left(\frac{1}{\left(s10E{-}9{+}\frac{1}{3300}{+}\frac{1}{1500}\right)}\right) + \left(\frac{1}{s10E{-}9{+}\left(\frac{1}{100}\right){+}\left(\frac{1}{s0.10{+}100}\right)}\right)}$$

$$H(j\omega) = \left.\frac{\left(\frac{1}{\left((j\omega)10E{-}9{+}\frac{1}{3300}{+}\frac{1}{1500}\right)}\right)}{\left(\frac{1}{\left((j\omega)10E{-}9{+}\frac{1}{3300}{+}\frac{1}{1500}\right)}\right) + \left(\frac{1}{(j\omega)10E{-}9{+}\left(\frac{1}{100}\right){+}\left(\frac{1}{(j\omega)0.10{+}100}\right)}\right)}\right|_{s=(j\omega))}$$

Hand Calculations - “The Fix”
Transfer Function H(s)

$$H(j12566) = \frac{\left(\frac{1}{\left((j12566)10E{-}9{+}\frac{1}{3300}{+}\frac{1}{1500}\right)}\right)}{\left(\frac{1}{\left((j12566)10E{-}9{+}\frac{1}{3300}{+}\frac{1}{1500}\right)}\right) + \left(\frac{1}{(j12566)10E{-}9{+}\left(\frac{1}{100}\right){+}\left(\frac{1}{(j12566)0.10{+}100}\right)}\right)}\Bigg|_{s=(j12566))}$$

$$H(j12566) = 0.91287 - j0.01565$$

$$H(j12566) = 0.9130\angle - 0.982^{\circ}$$

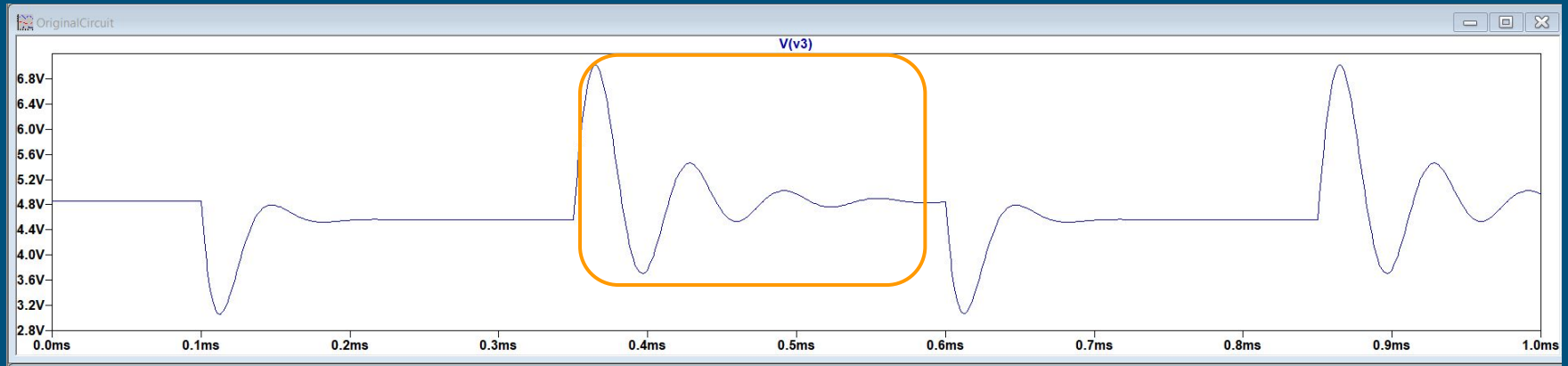
Hand Calculations - “The Fix” Vout

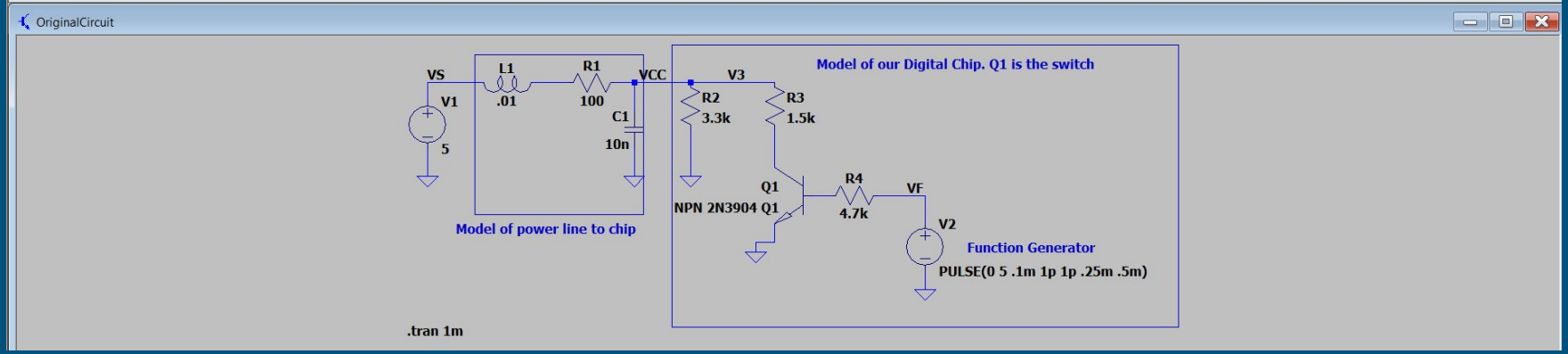
$$v_o(t) = A|H(j\omega)|cos(\omega t - \theta(\omega)$$

$$v_o(t) = (5)|(0.9130)|cos(12566t - (-0.982^\circ))$$

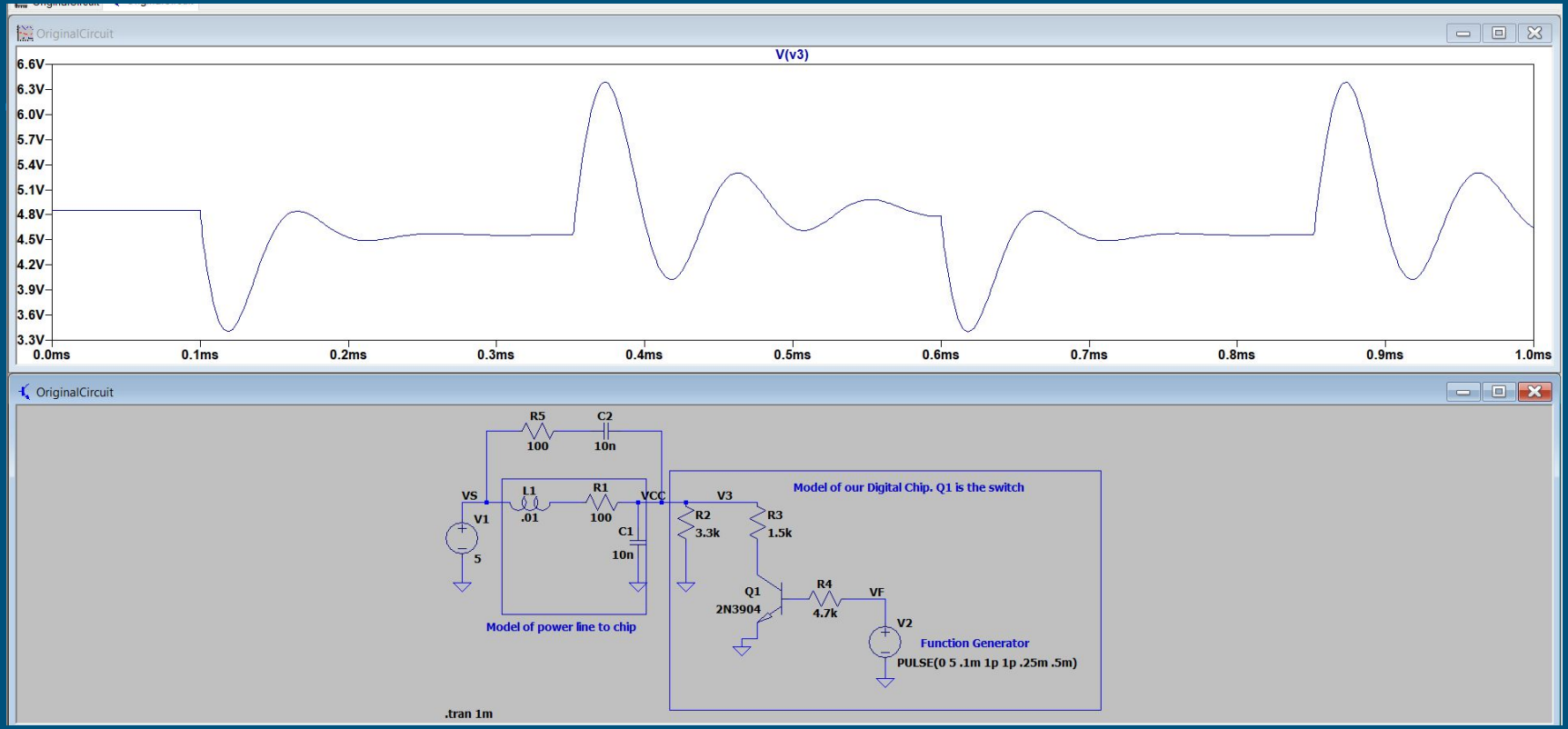
$$v_o(t) = 4.565 \cdot cos(12566t + 0.982^\circ)V$$

Noise in Original Circuit

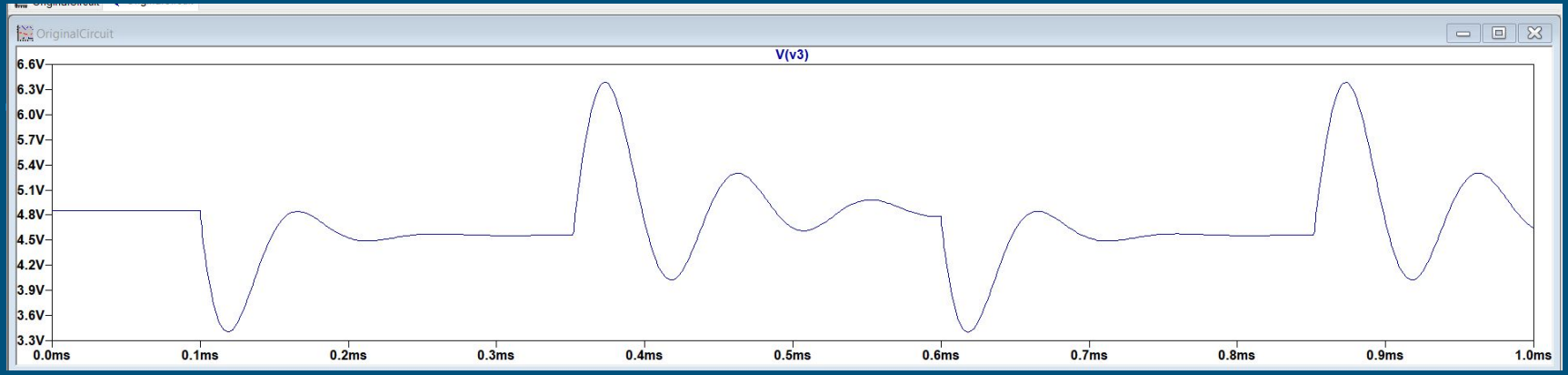




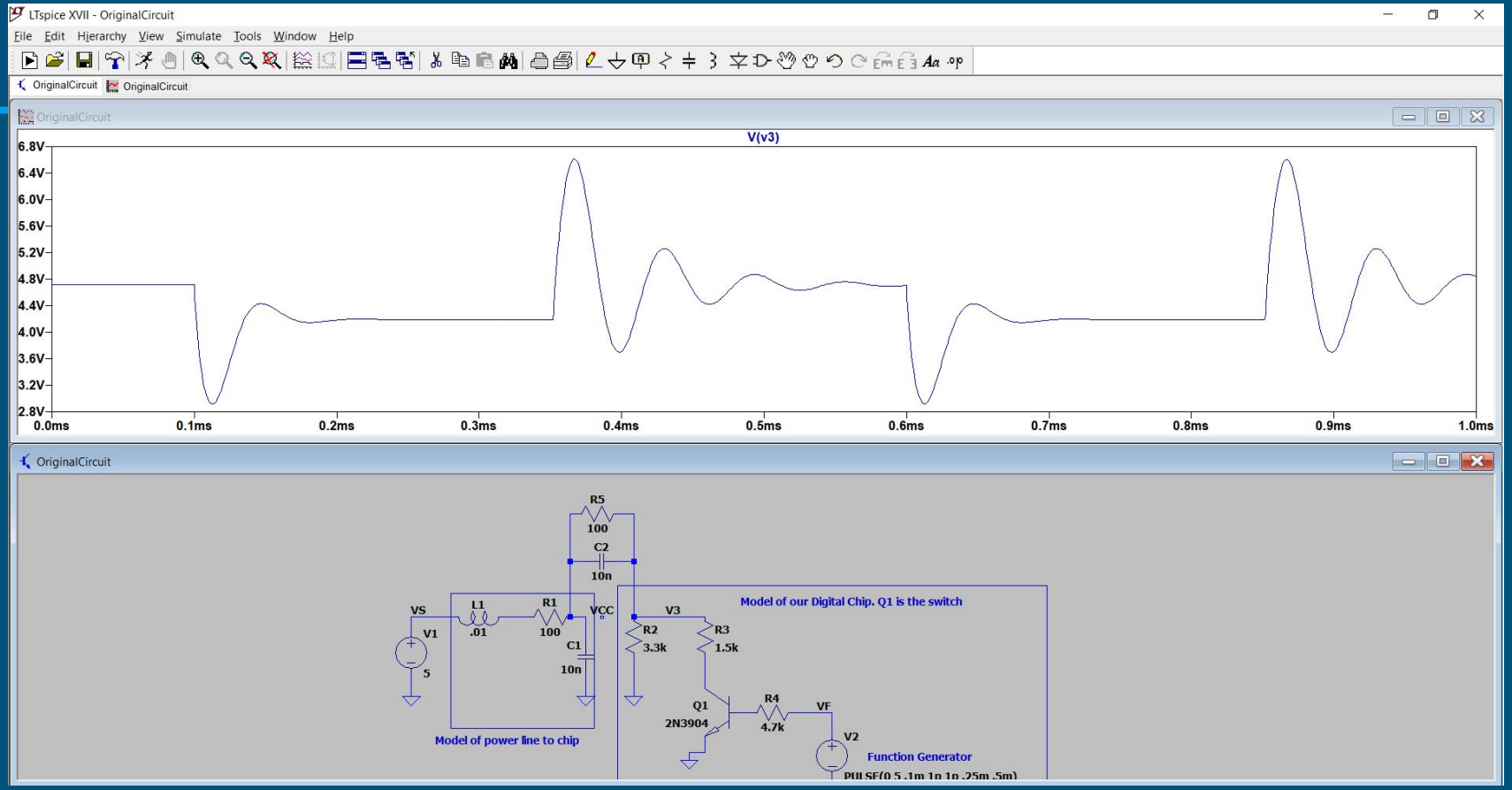
Series RC Circuit Added



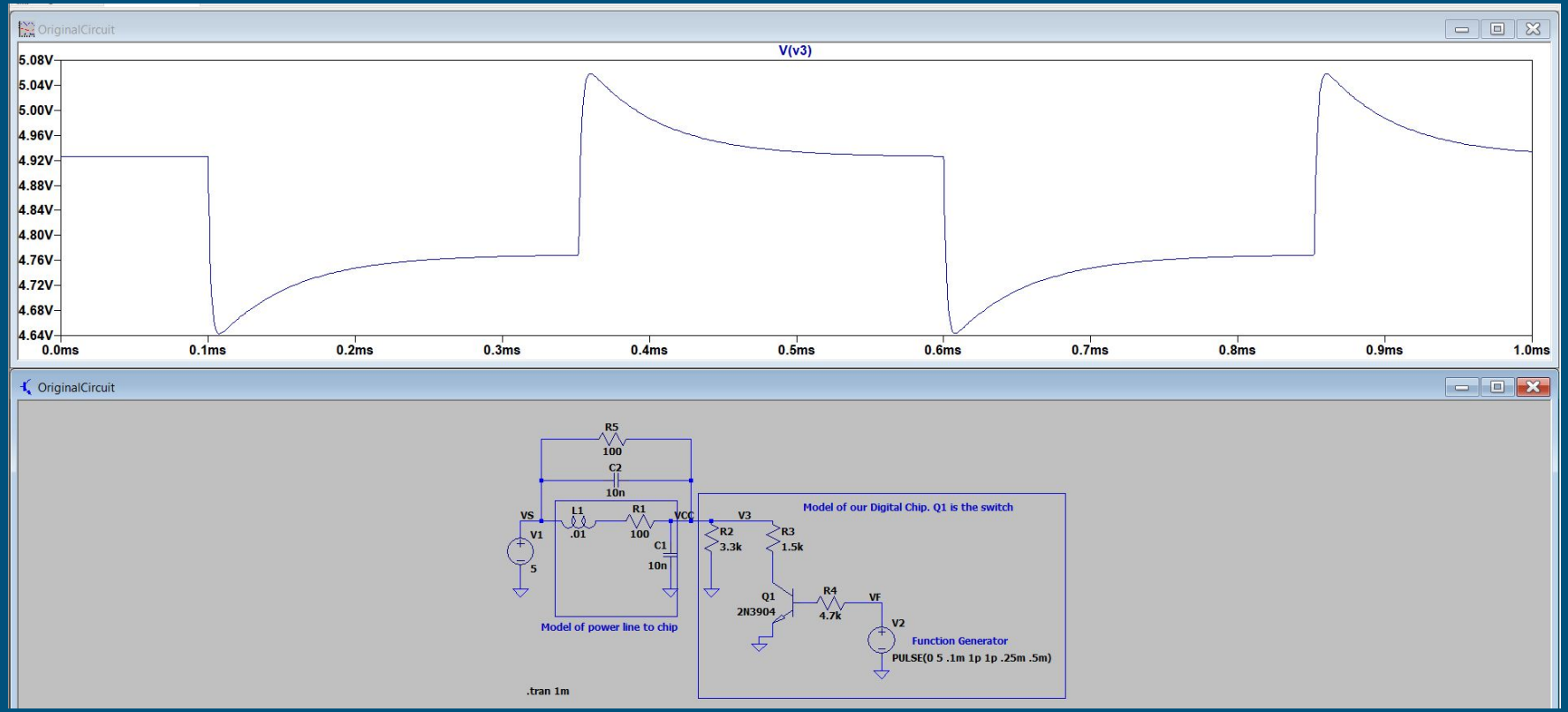
Series RC Circuit Added



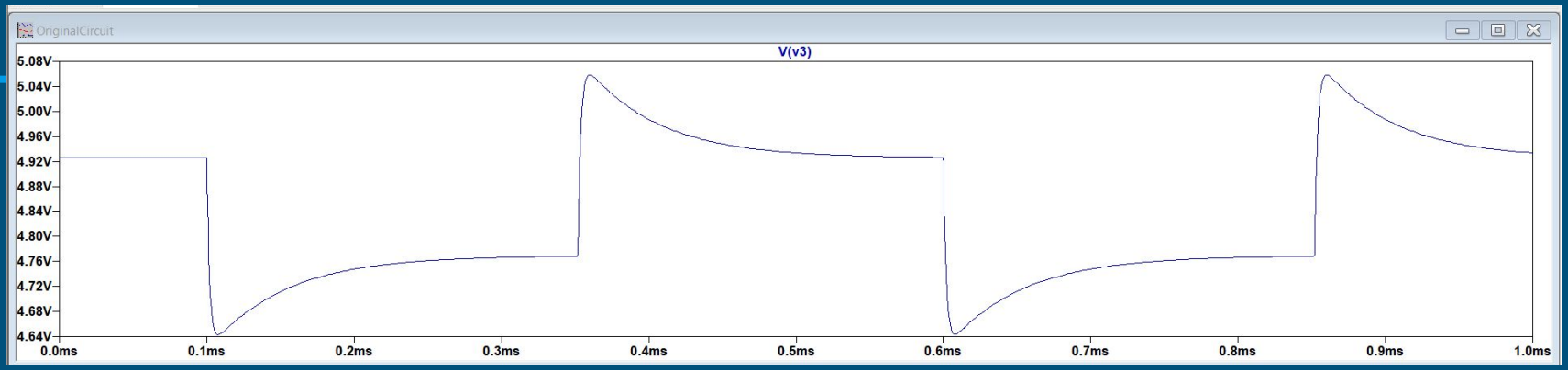
First Parallel RC Circuit Added

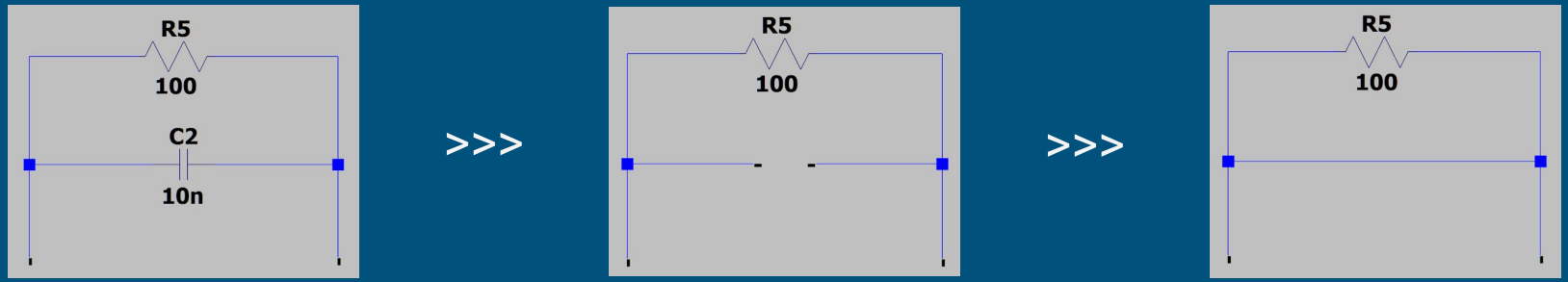


Better Parallel RC Circuit Added

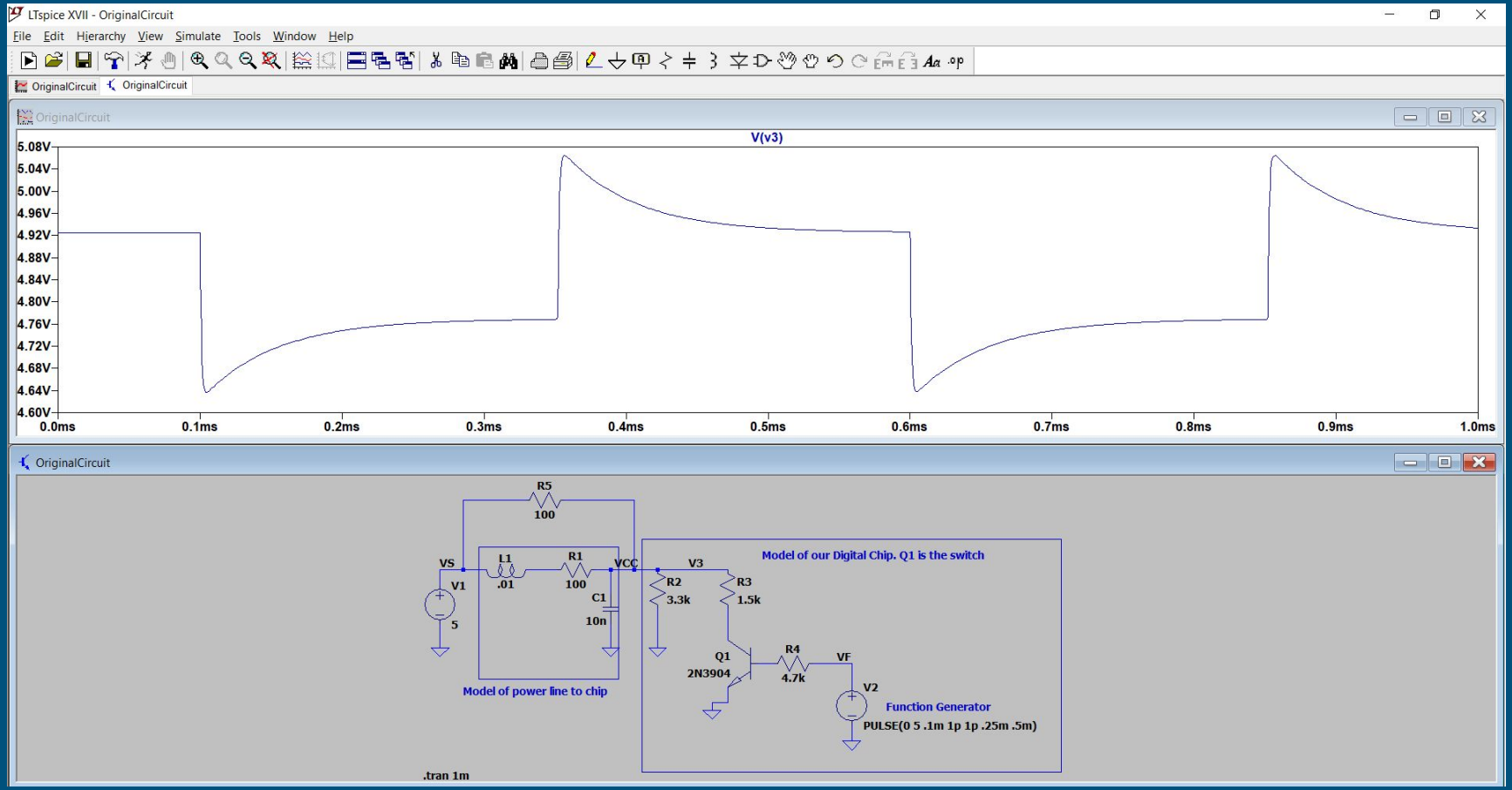


Better Parallel RC Circuit Added





Results Close To 100 Ohm Resistor Alone

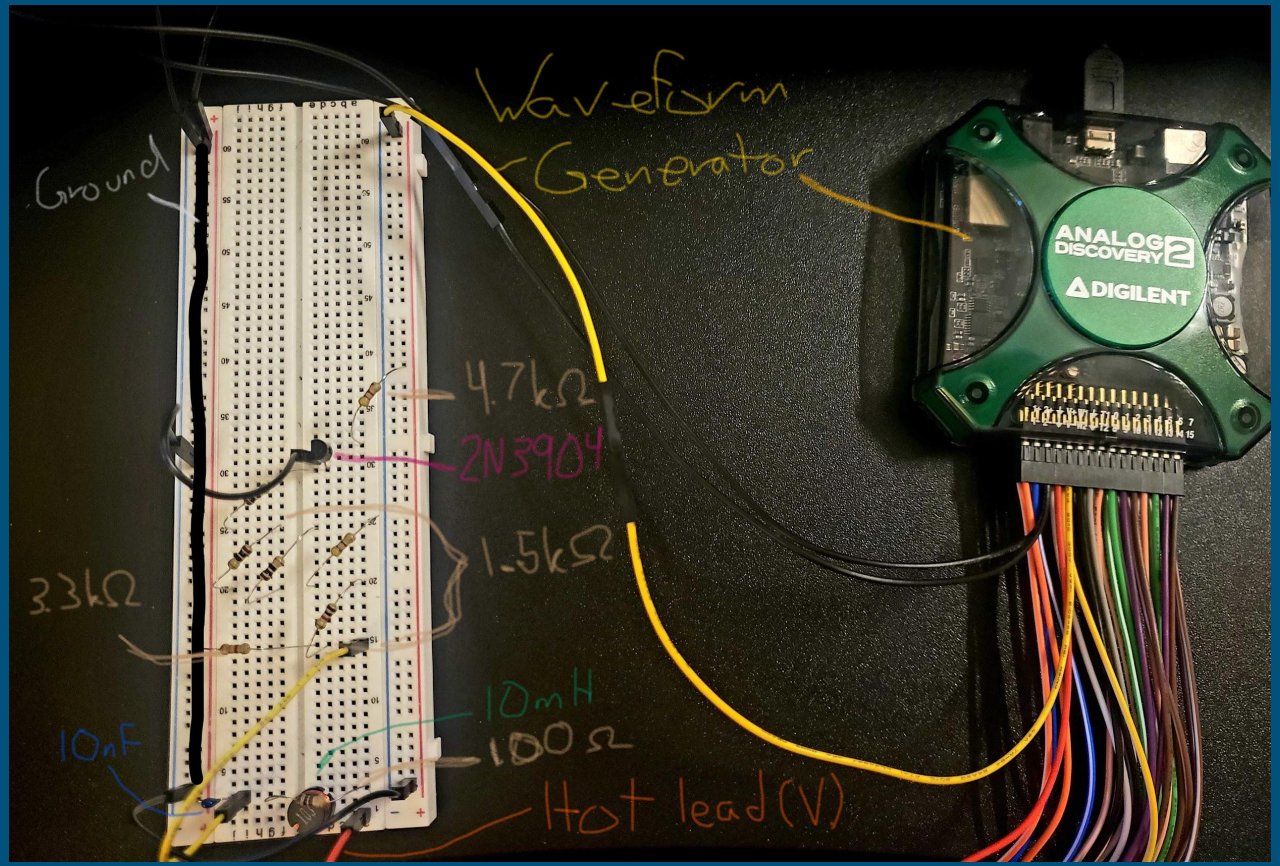


RC vs. RL Circuit Noise

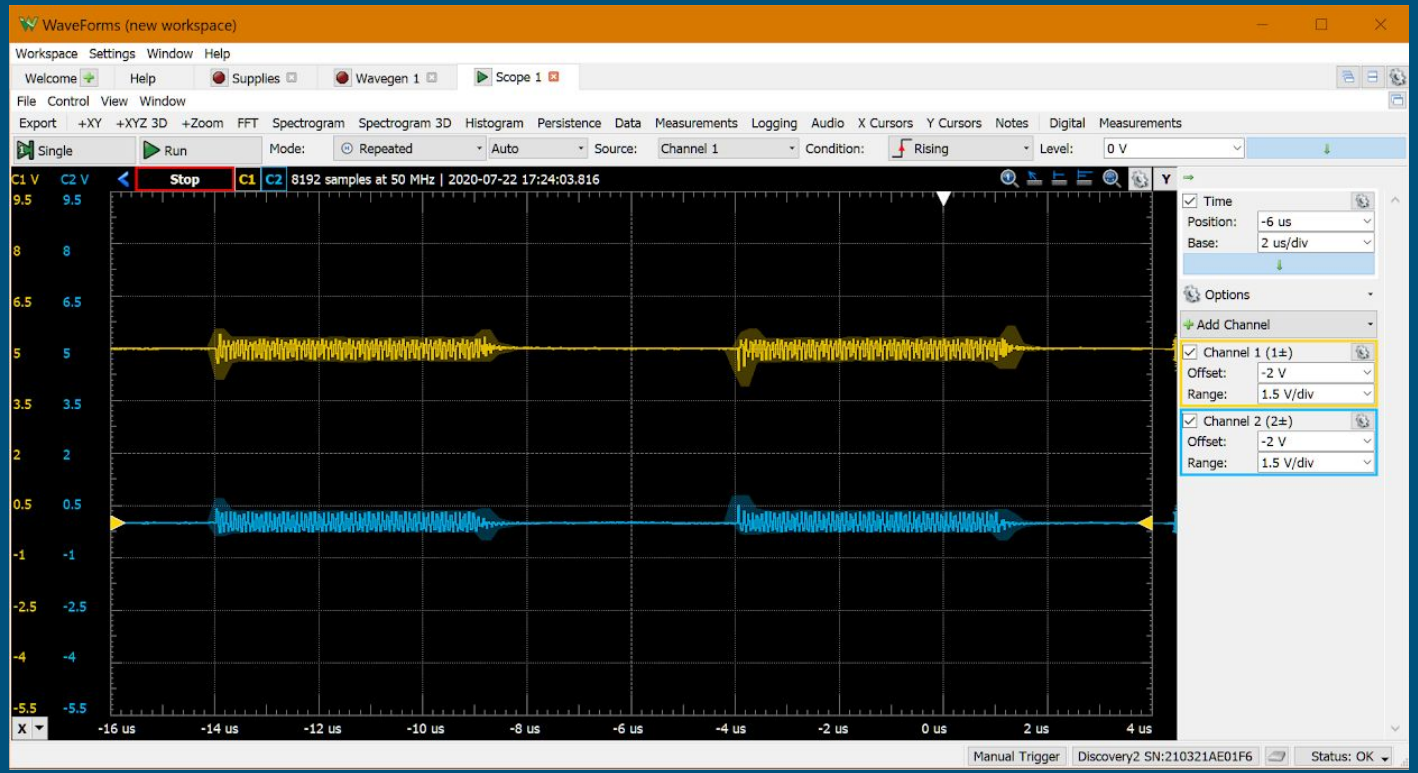
An inductor introduces more noise to the circuit than a capacitor.

Placing components in parallel is more effective for noise reduction than placing them in series.

Physical Circuit without Filter

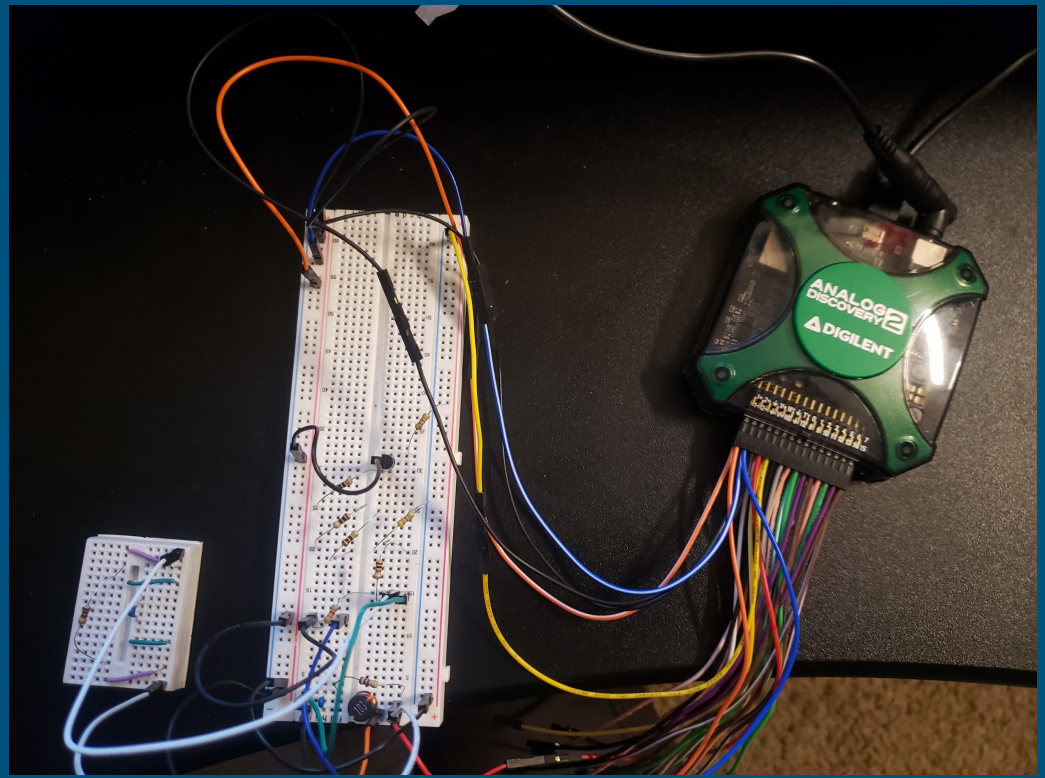


Physical Circuit without Filter



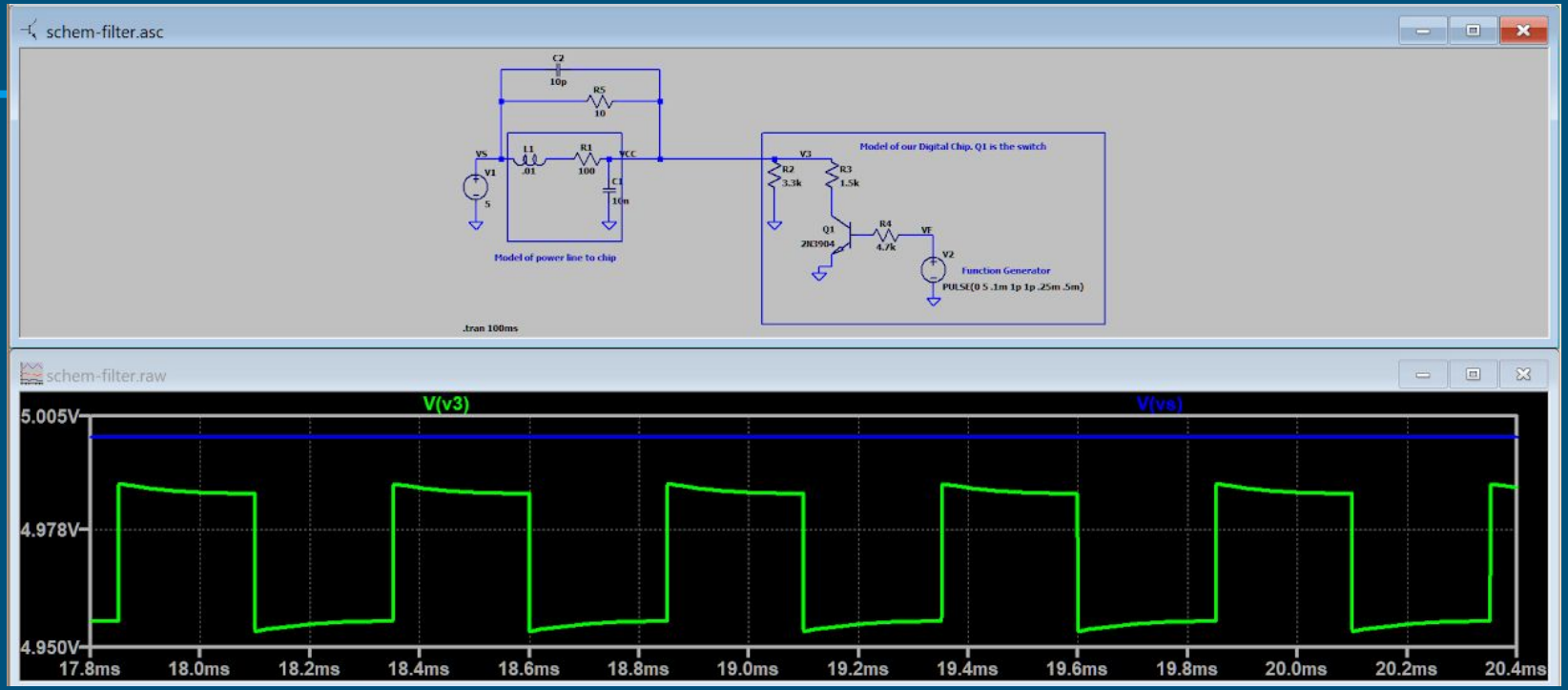
Note: we haven't gotten to fully troubleshoot the waveform generator and make sure we had the correct set-up. Will improve for next project if able to.

Physical Circuit with Filter



Note: Relating to issue on previous slide, no analysis of circuit with filter.

Conclusion: Best Noise Reduction Circuit



Best Components from Appendix H: 10 pF capacitor in parallel to 10 Ω resistor

Questions?