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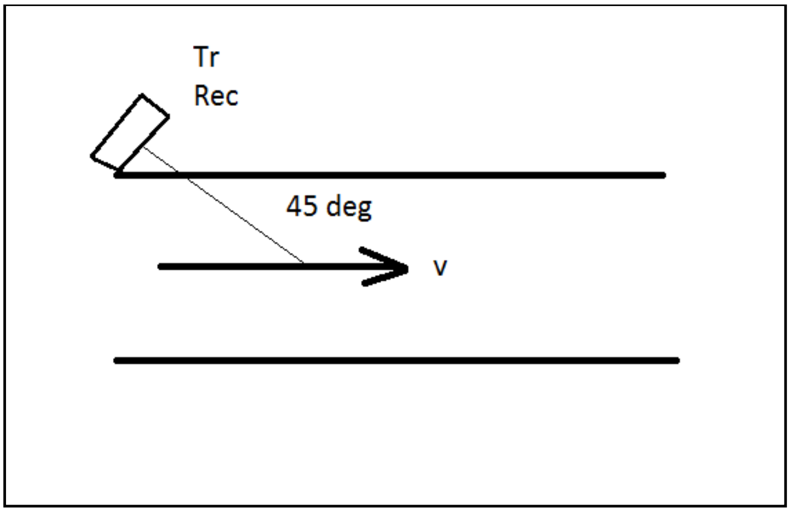
1.



Diameter= 2cm => Radius= 1cm = 0.01m
Area= πr^2 = 3.14 x 0.01 x 0.01 = 3.14 x 10^{-4} m2
Frequency = 40kHz
$V_p = F_0 \lambda$
λ= 331/40000 = 8.275mm
$|Kr|\cos45^\circ = |Ki|\cos45^\circ = 2\pi/\lambda \times \cos45$ = 536.632

Case 1
Flow 1 = 0.2L/sec = 0.2 x 10^{-3} m/sec
Velocity = Flow / Area= 0.636 m/sec
$F_d = [|Kr|\cos45^\circ + |Ki|\cos45^\circ]$ x Velocity / 2π

= [536.632 + 536.632] x 0.636 / 6.28

= **108.86 Hz**

Case 2
Flow 2 = 0.1L/sec = 0.1 x 10^{-3} m/sec
Velocity = Flow / Area= 0.318 m/sec
$F_d = [|Kr|\cos45^\circ + |Ki|\cos45^\circ]$ x Velocity / 2π

= [536.632 + 536.632] x 0.318 / 6.28

= **54.43 Hz**

Case 3
Flow 3 = 0.05L/sec = 0.05 x 10^{-3} m/sec
Velocity= Flow / Area= 0.159 m/sec
$F_d = [|Kr|\cos45^\circ + |Ki|\cos45^\circ]$ x Velocity / 2π

= [536.632 + 536.632] x 0.159 / 6.28

= 27.17 Hz

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DESIGN

There are three flows in the question. Flow 1 equals 0.2 L/sec, Flow 2 equals 0.1 L/sec and Flow 3 equals 0.05 L/sec. This is repeated for three cycles. The circuit has got nine different sine waves of frequencies 108.86 Hz, 54.43 Hz and 27.17 Hz with corresponding delays.

Flow 1- Frequency 108.86 Hz

Since its duration is 1 second, it exists from 0th-1st second, 4th-5th second, 8th-9th second for the three cycles. All the three sine waves are summed using a summing amplifier of gain 3.

Flow 2- Frequency 54.43 Hz

Since its duration is 1 second, it exists from 1st-2nd second, 5th-6th second, 9th-10th second for the three cycles. All the three sine waves are summed using a summing amplifier of gain 3.

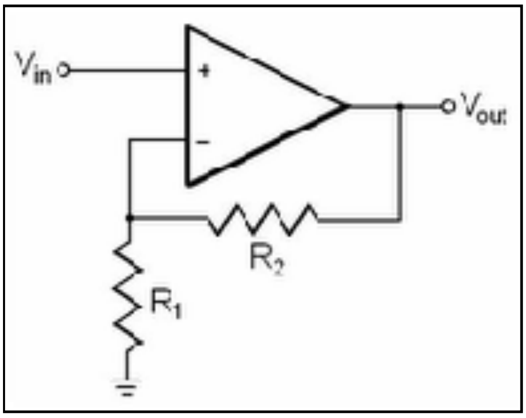
Flow 3- Frequency 27.17 Hz

Since its duration is 2 seconds, it exists from 2nd-4th second, 6th-8th second, 10th-12th second for the three cycles. All the three sine waves are summed using a summing amplifier of gain 3.

The summed input 1, input 2, input 3 are given to another summing amplifier of gain 3 to generate the overall input which is a sine wave of frequencies corresponding to the three flows for three cycles.

Summing Amplifier

Its a non inverting amplifier.
Gain= 1 + R_2/R1
Let R_2= 2K & R_1= 1k
=> Gain= 3

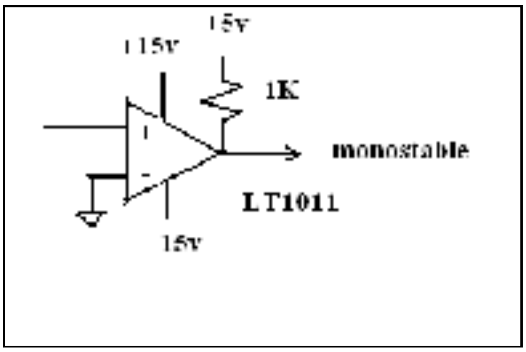


The gain was chosen to be 3 because the three inputs together act as a voltage divider network and the effective voltage equals 1/3 volts. Thus the net sum of voltage is boosted by a factor of 3 to produce a sine wave of unity magnitude.

Summing amplifiers were used to add the three sets of sine waves with corresponding delays to get three sine waves, which is once again added with a summing amplifier to get the net input i.e, sine wave with three frequencies for 12 seconds.

LT1011

It acts a zero crossing detector. Whenever the input sine wave falls to zero, a square pulse is generated. This converts a sine wave ranging from +1V to -1V input into a square wave ranging from +5V to 0V.



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<u>555 Monostable Multivibrator</u>

The trigger pin is connected to a RC network.

Time constant= $1 \times 1000 \times 0.01 \times 10^{-6}$

= 10 microseconds

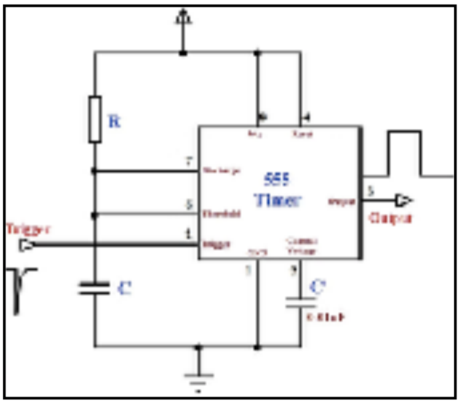
The trigger pin activates for $V_{cc}/3$ at the end of 10 microseconds.

Monostable Pulse Duration= 1.1RC

= $1.1 \times 8.35 \times 1000 \times 1 \times 10^{-6}$

= 9.185 milliseconds

10nF capacitor is used before pin 5 to block DC, it prevents noise from being seen at the output.



<u>Low Pass Filter(LPF)</u>

There are two low pass filters used in the circuit. Since the entire operation takes place at low frequencies, it behaves like an integrator. The first LPF corresponds to flow and the second corresponds to volume i.e, integral flow.

<u>1st LPF</u>

It is designed in such a way that the time constant of the filter is more than the longest doppler period.

Highest Frequency= 108.86 Hz

Time Period= 1/108.86= 9.186 milliseconds

Assume the period to be 9.2 milliseconds(slightly higher than the period of longest doppler)

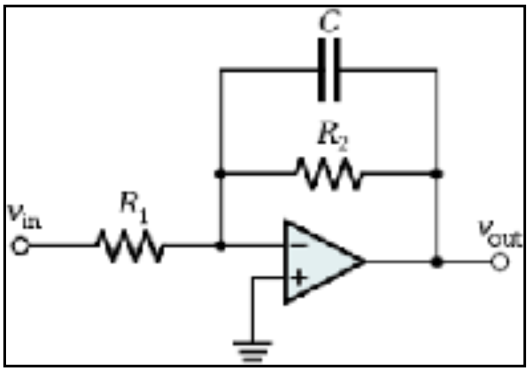
$9.2 \times 10^{-3} = R_2C$

Let C= 10 uF

$\Rightarrow R_2 = 920\Omega$

Since Gain=1, $R_1 = R_2$

$\Rightarrow R_1 = 920\Omega$



<u>2nd LPF</u>

The second LPF is designed for a time constant 60 seconds.

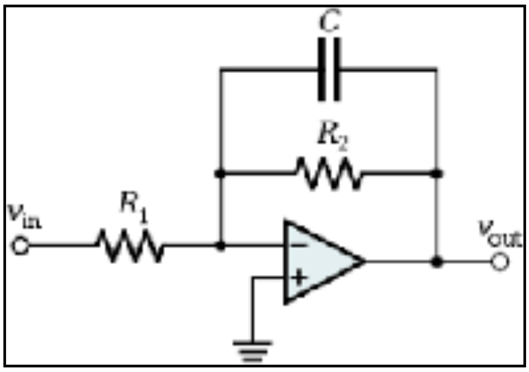
$60 = R_2C$

Let C= 10 uF

$\Rightarrow R_2 = 920\Omega$

Since Gain=1, $R_1 = R_2$

$\Rightarrow R_1 = 920\Omega$



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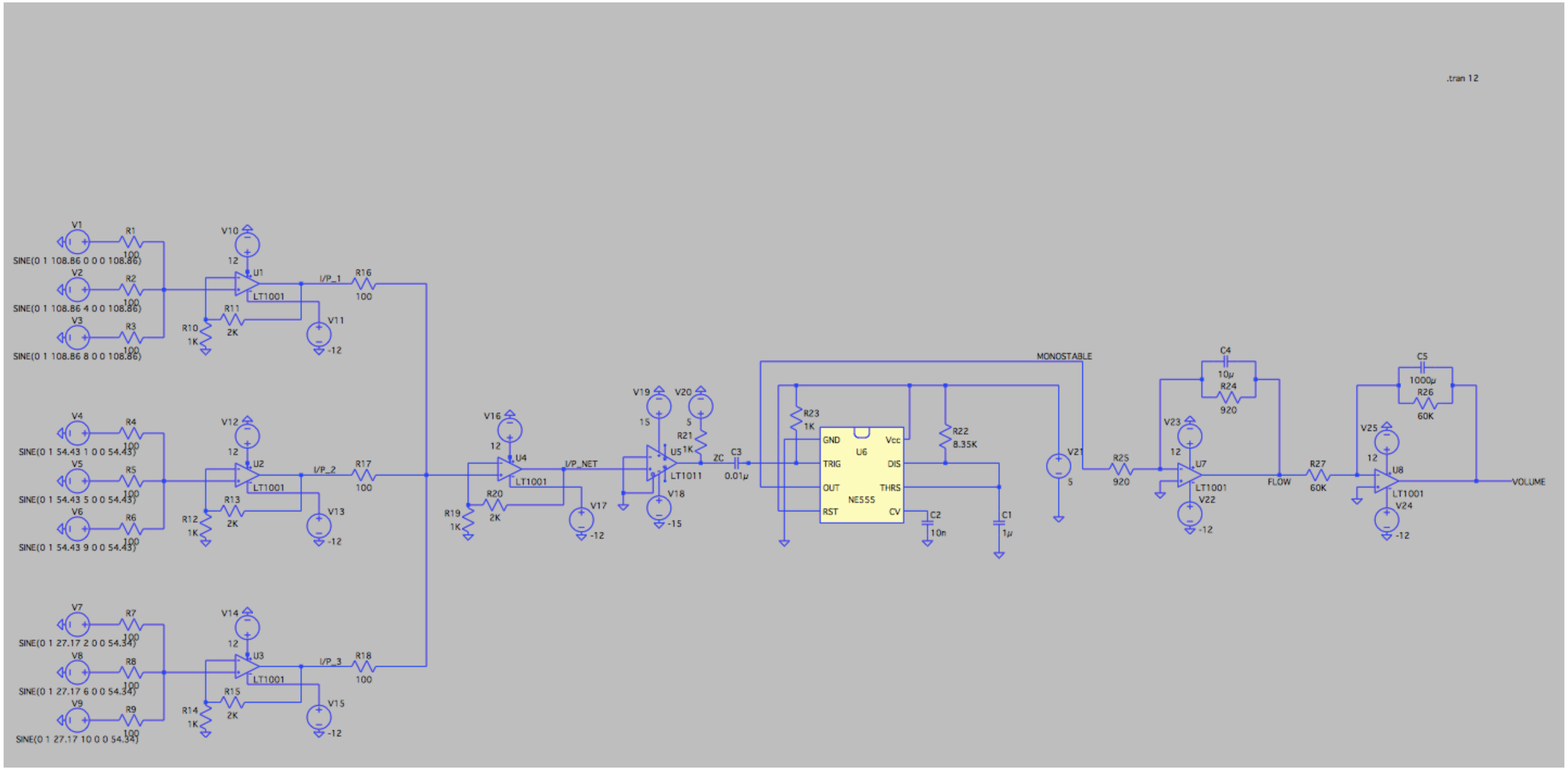
LTSPICE CIRCUIT



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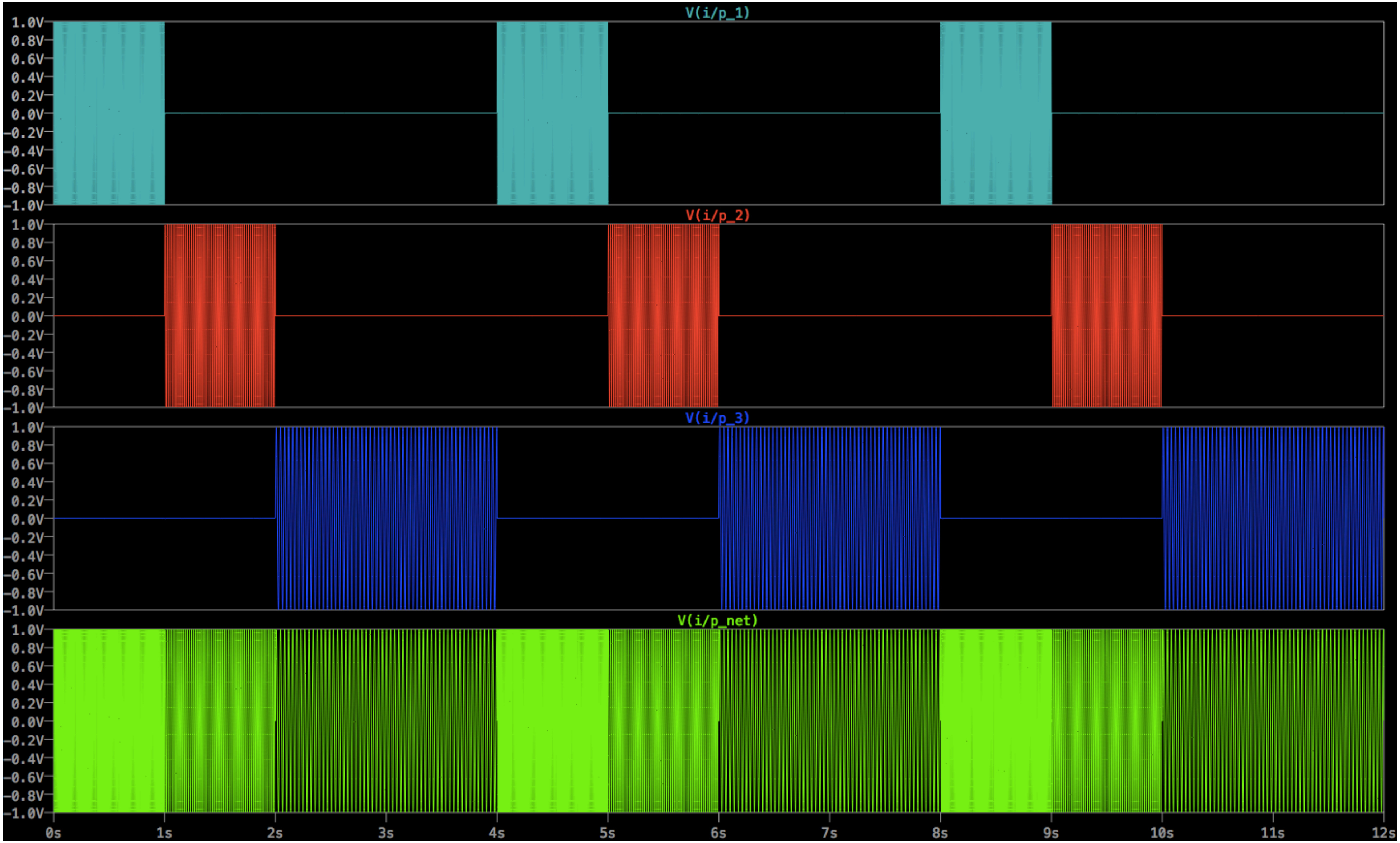
LTSPICE INPUT SINE WAVES



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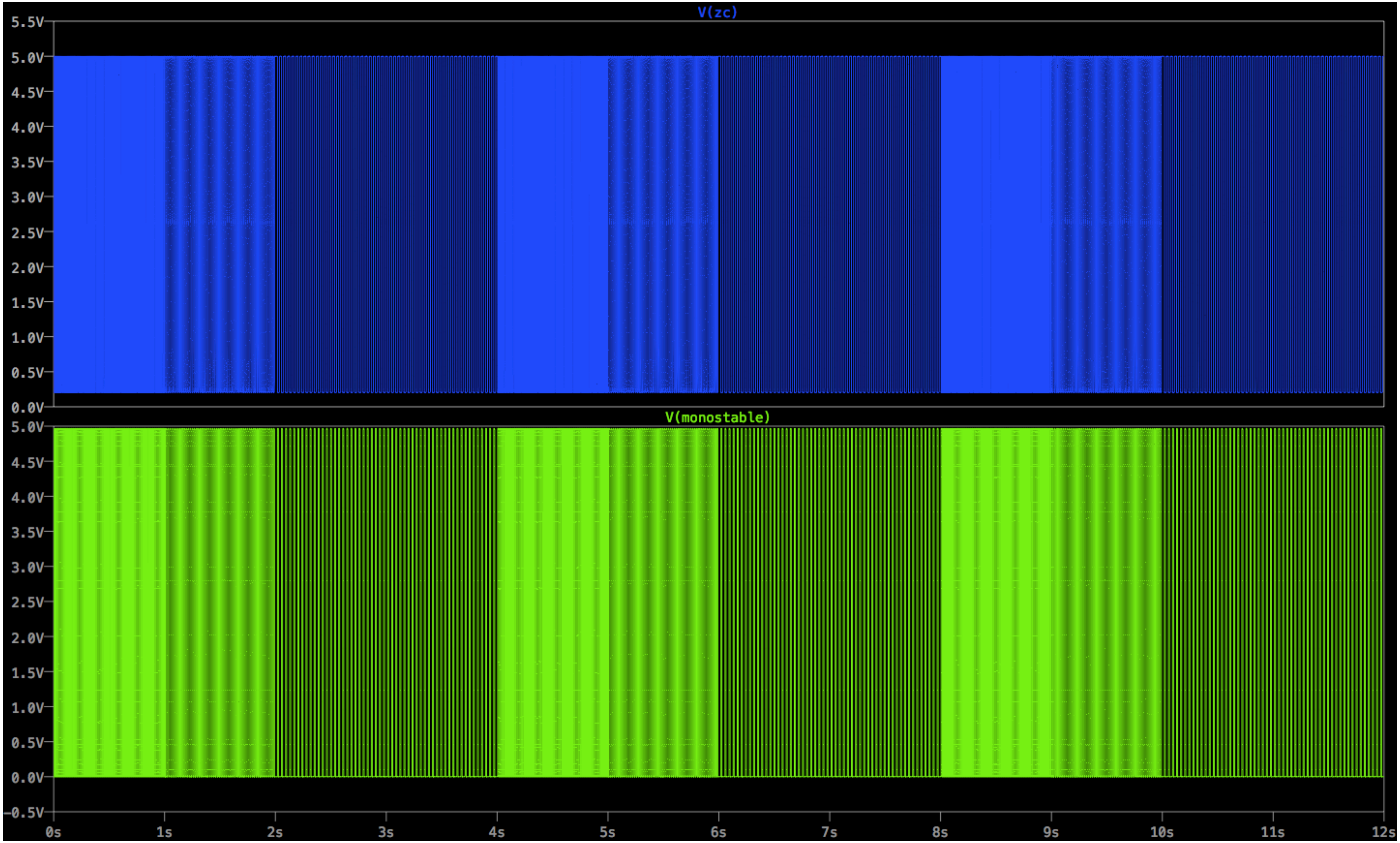
LTSPICE ZERO CROSSING AND MONOSTABLE OUTPUT



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LTSPICE FLOW AND VOLUME OUTPUT