Shaping Sounds: Design of a Diode-Ladder Voltage Controlled Filter

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Topics to Cover

1. Purpose of a VCF
2. Theory: Resonance
3. Theory: diodes as voltage-controlled resistors
4. Characterization

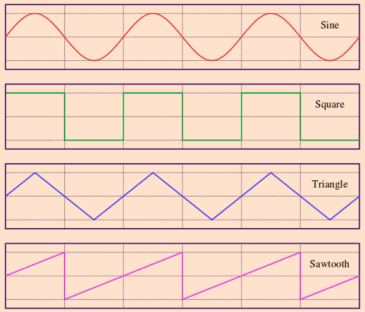
Background: Sounds and Signals

We take a lot of ideas from these guys!

Basic Operation of a Synthesizer

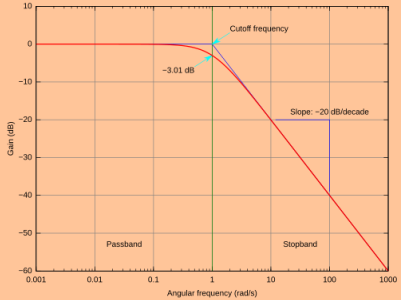
1. Make a signal

Signal Generators!



2. “Shape” a signal

Filters!

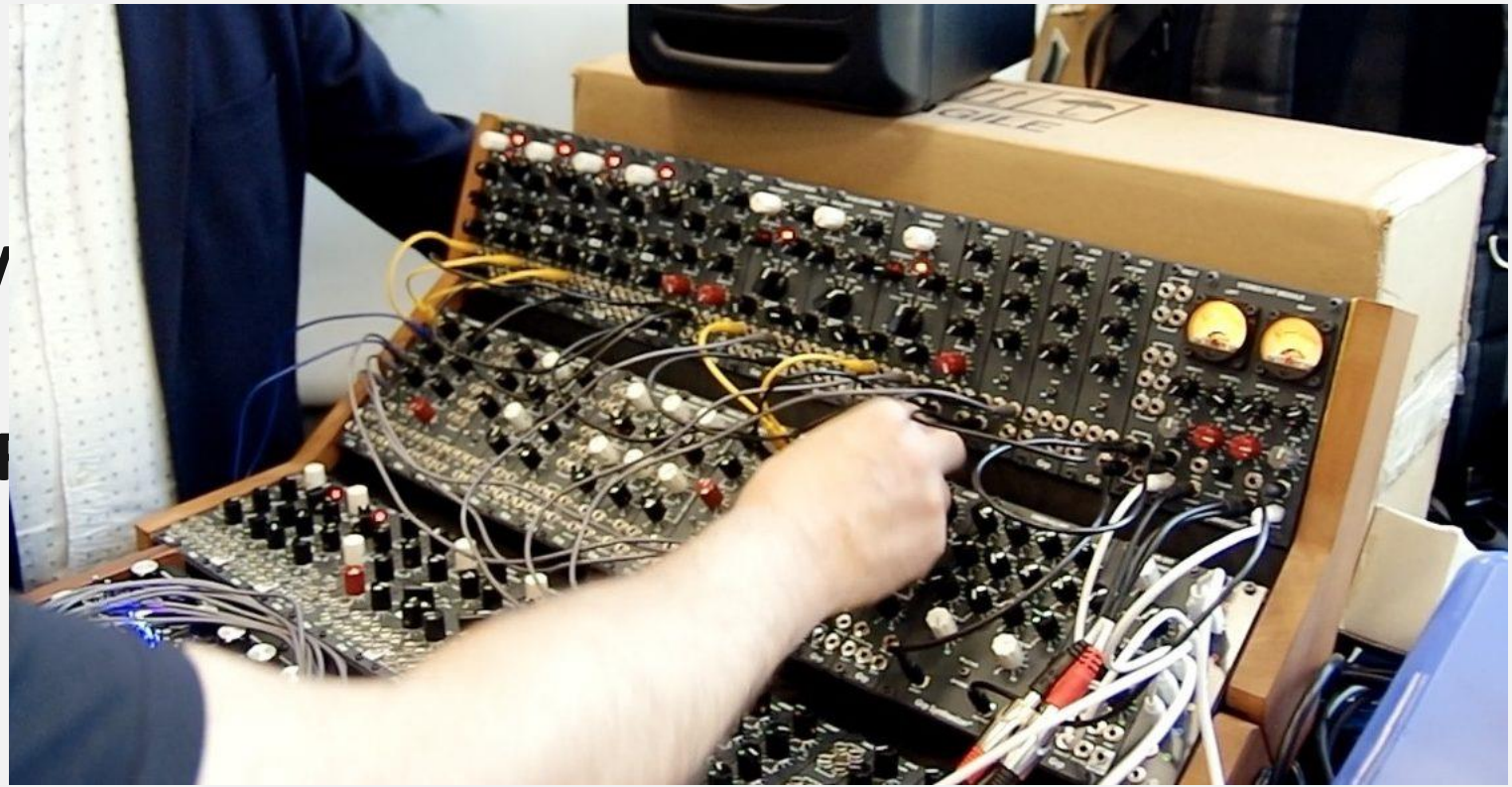


3. Output the sound

Speakers!

Design Considerations

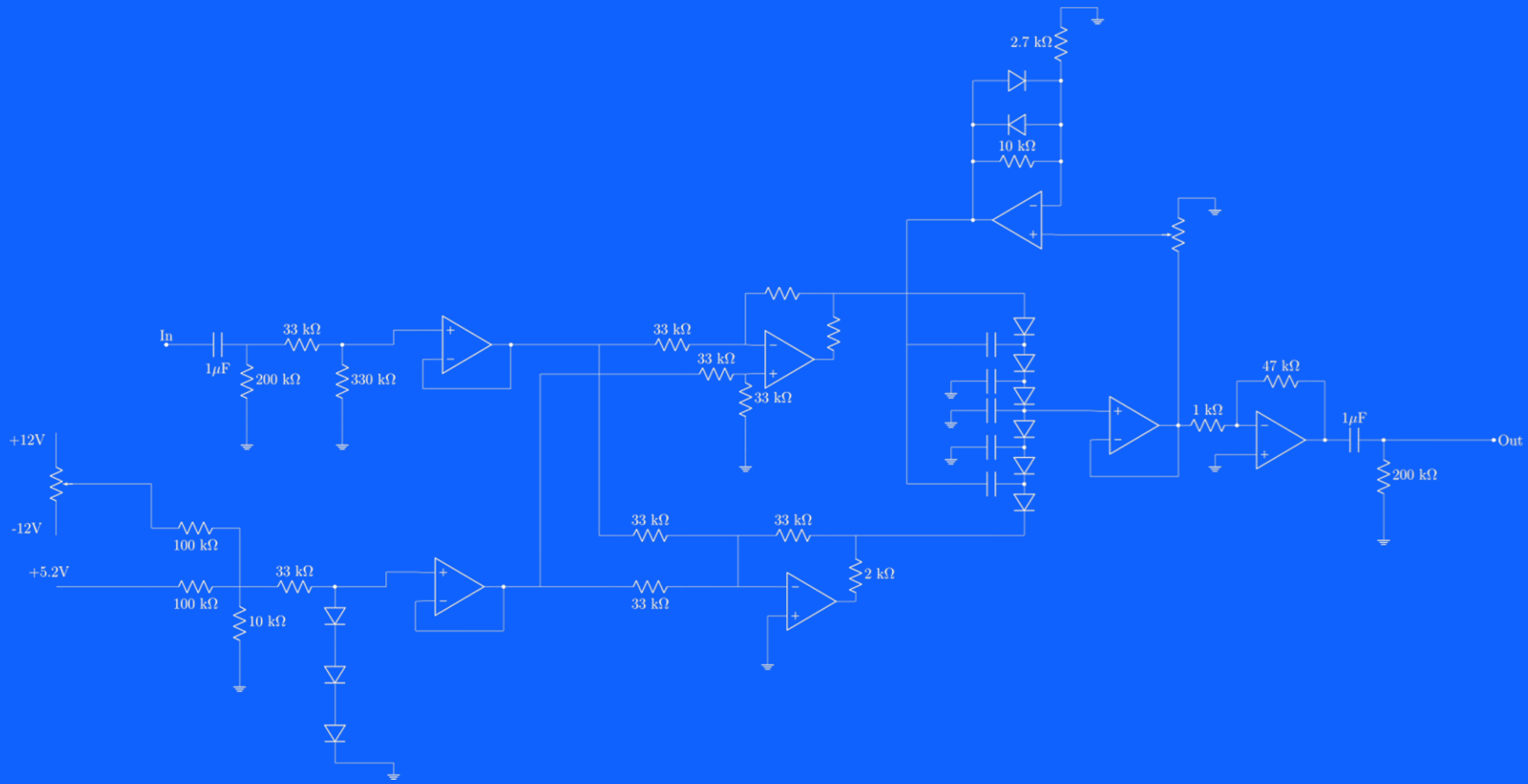
- V
- I



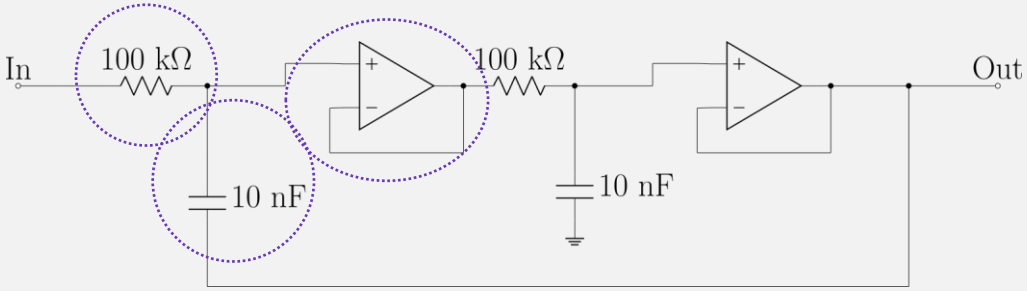
Design Considerations

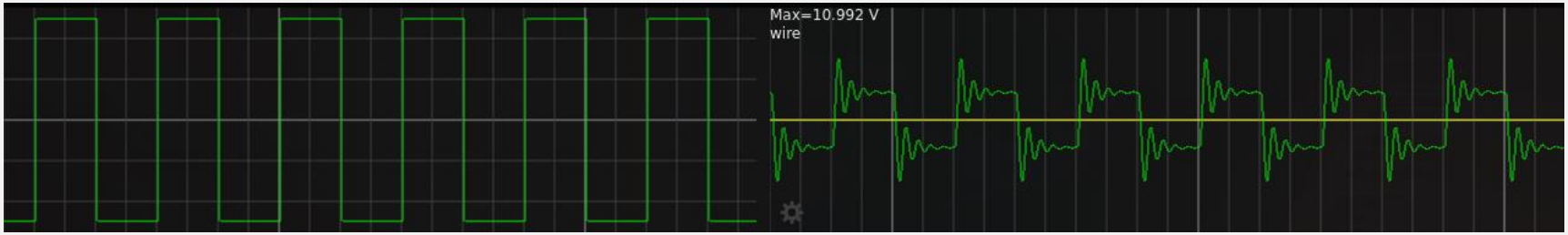
- **Voltage Control:** lets an artist adjust some dials and switches to get the sound they want
- **Robustness:** Must operate on a huge range of frequencies with consistency
- **Must** tune cutoff and resonance at least

Outcome...


2.7 kΩ
10 kΩ
In
1μF
33 kΩ
200 kΩ
330 kΩ
33 kΩ
33 kΩ
33 kΩ
47 kΩ
1 kΩ
1μF
Out
200 kΩ
+12V
-12V
100 kΩ
+5.2V
100 kΩ
33 kΩ
10 kΩ
33 kΩ
33 kΩ
2 kΩ
33 kΩ

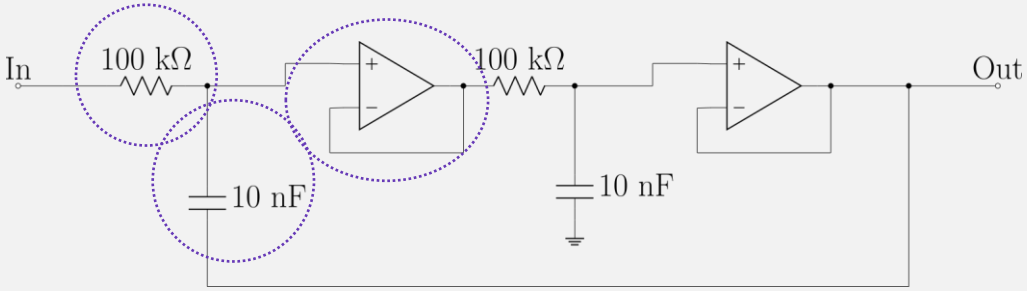
Basic Resonant Filters

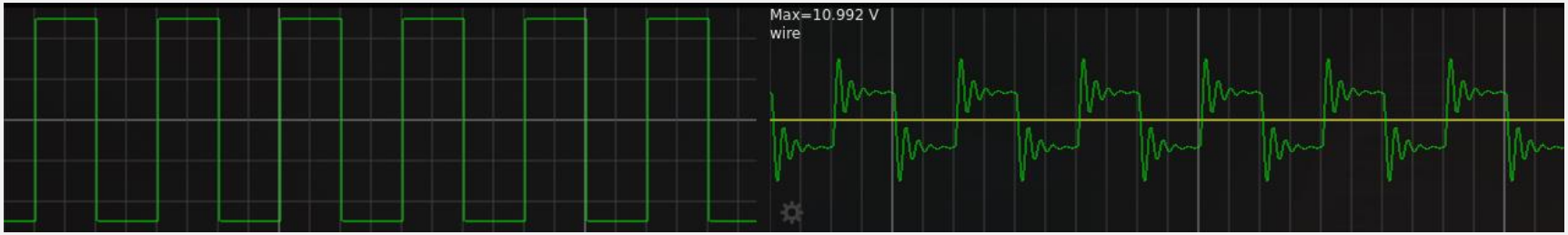




Interesting, but not very useful yet!

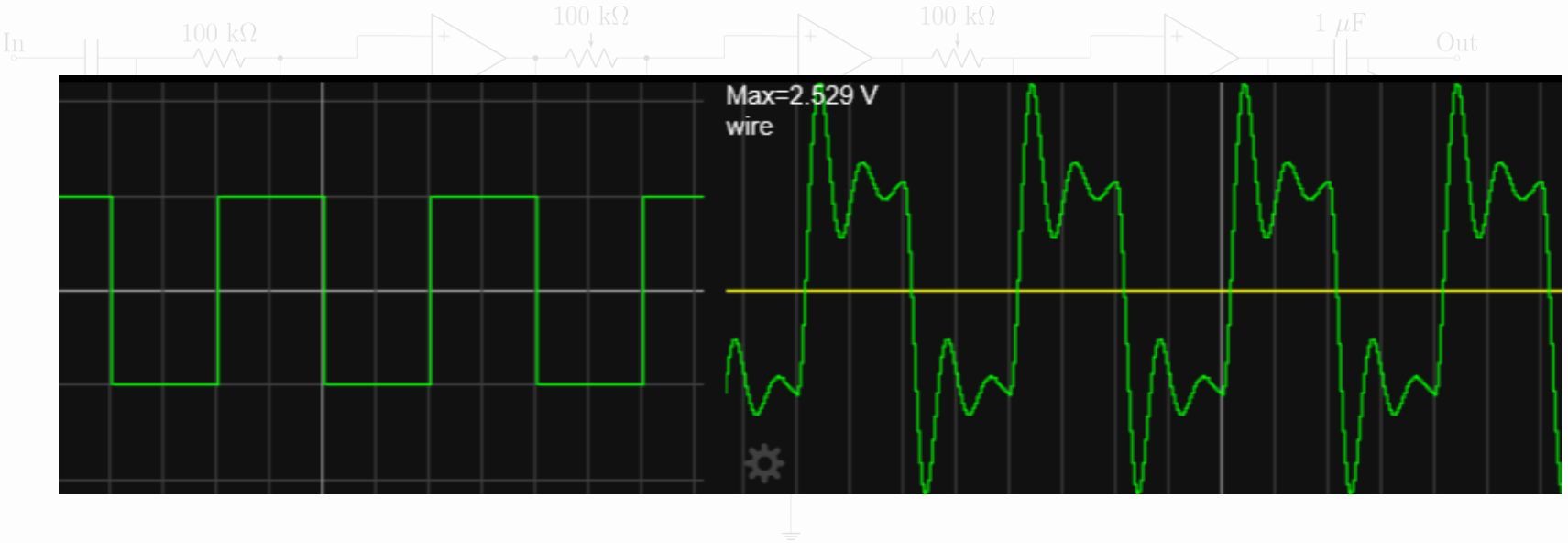
Basic Resonant Filters





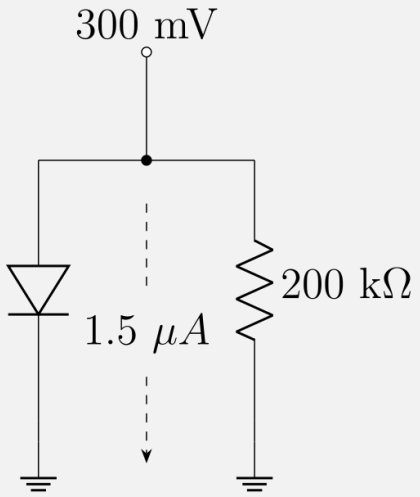
Interesting, but not very useful yet!

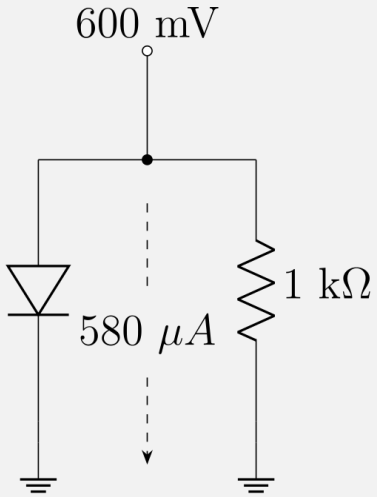
The Fully Resonant Low Pass

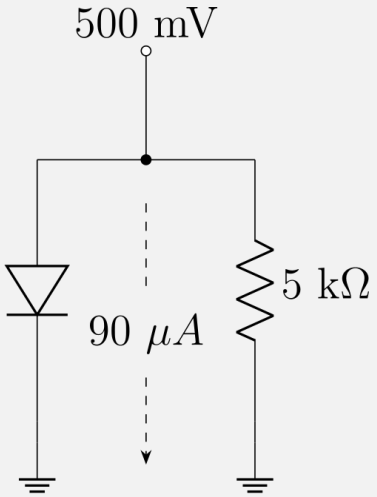


Not quite the circuit we end up with,
but this is very close...

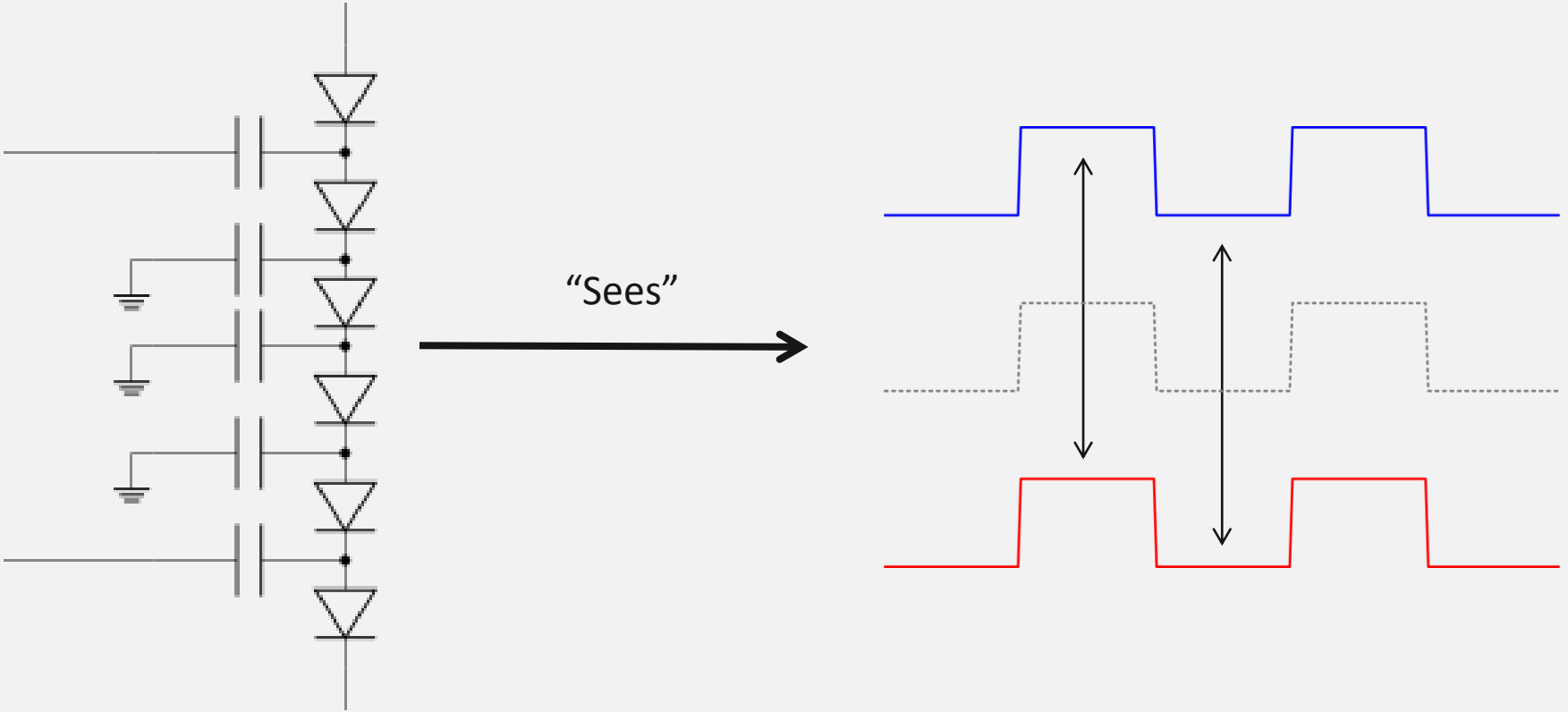
Diodes as Voltage Controlled Resistors



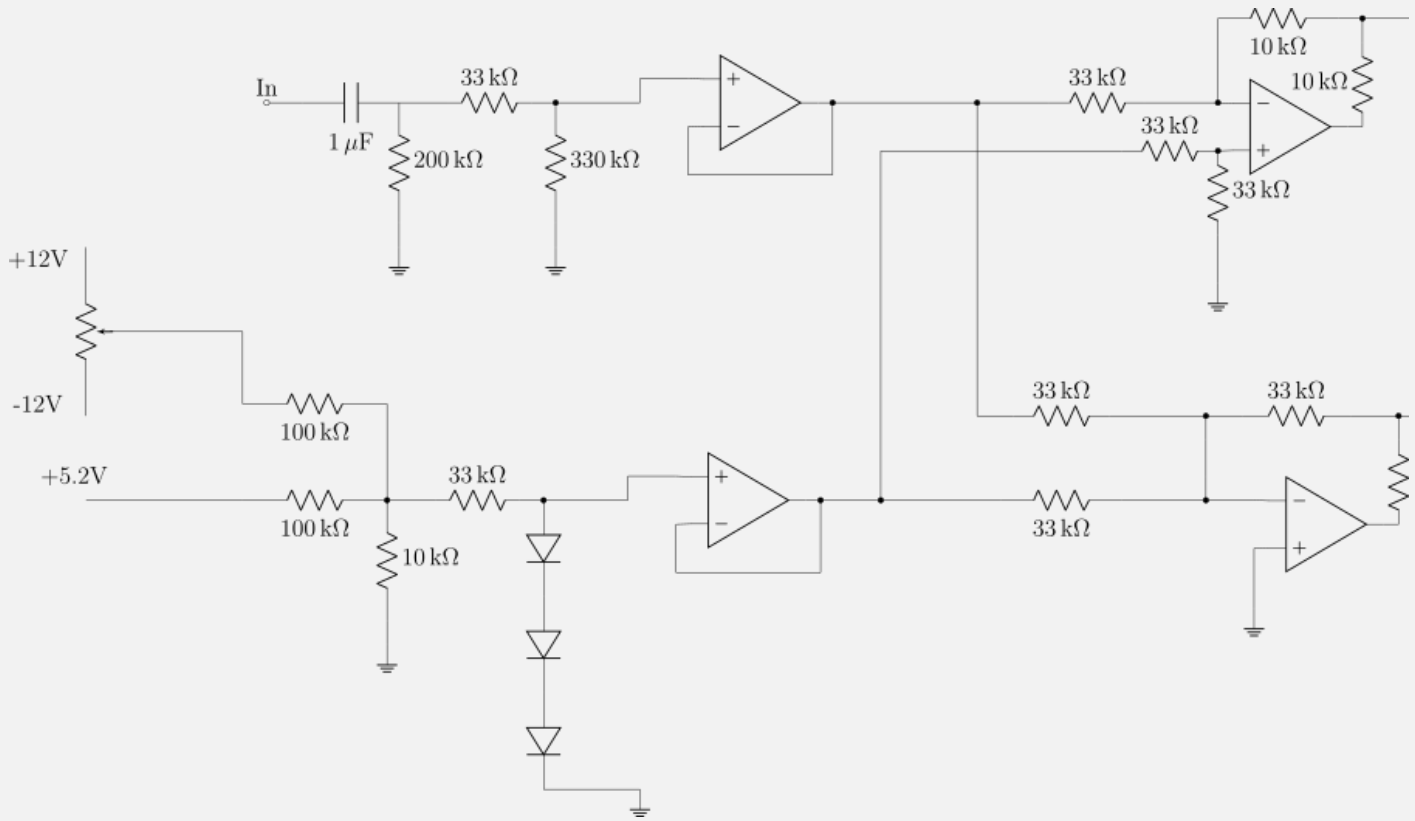




The Multi-Pole Diode Ladder

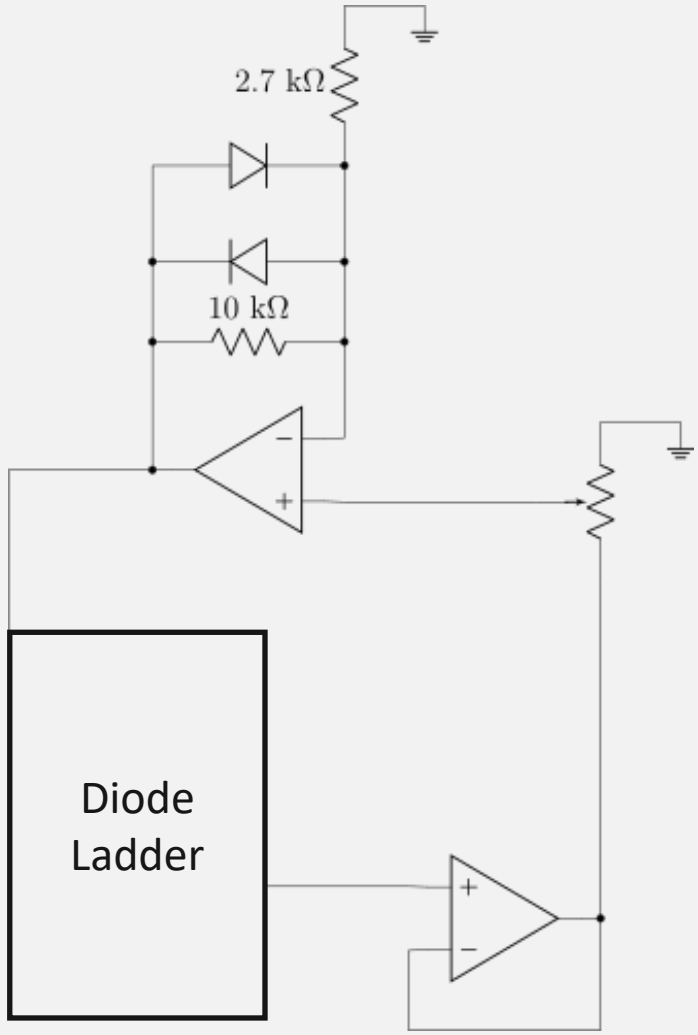


Input Stage and Driver

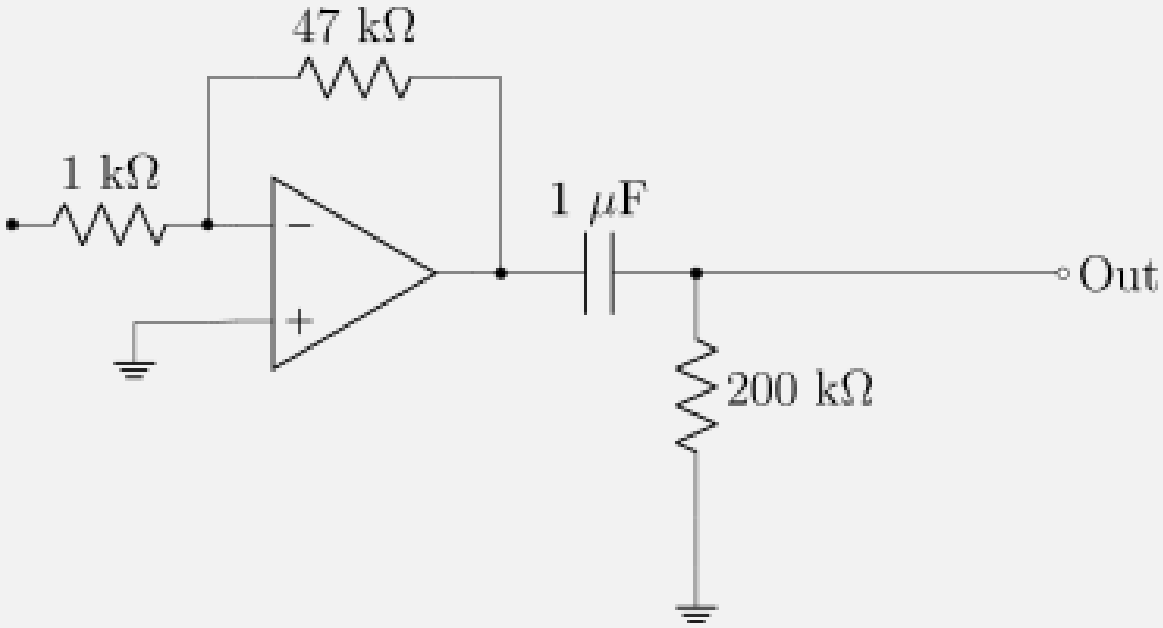


Resonance

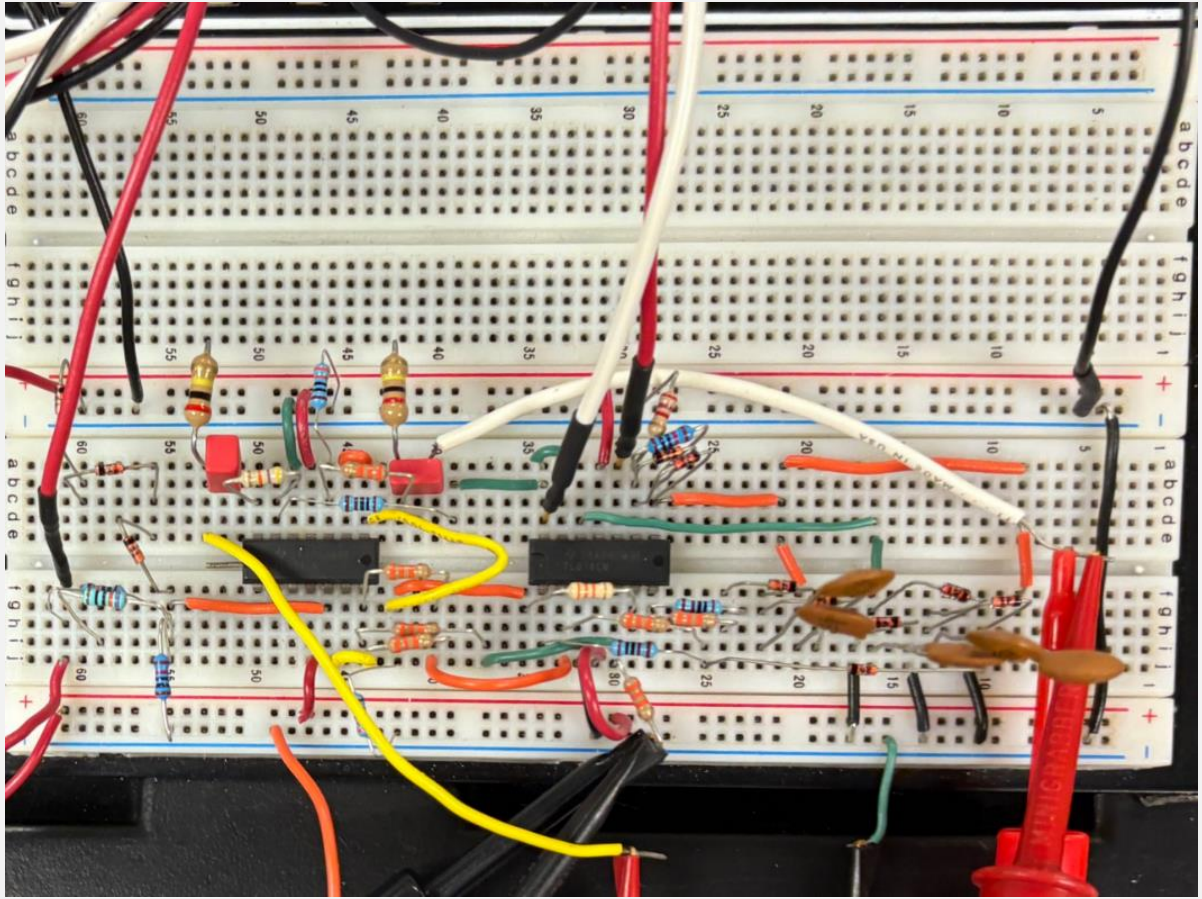
- Same as the fully resonant LPF, just with some mystery diodes
- Resonance goes into caps on diode ladder, giving the whole signal VC
- Used in certain KORG synthesizers!



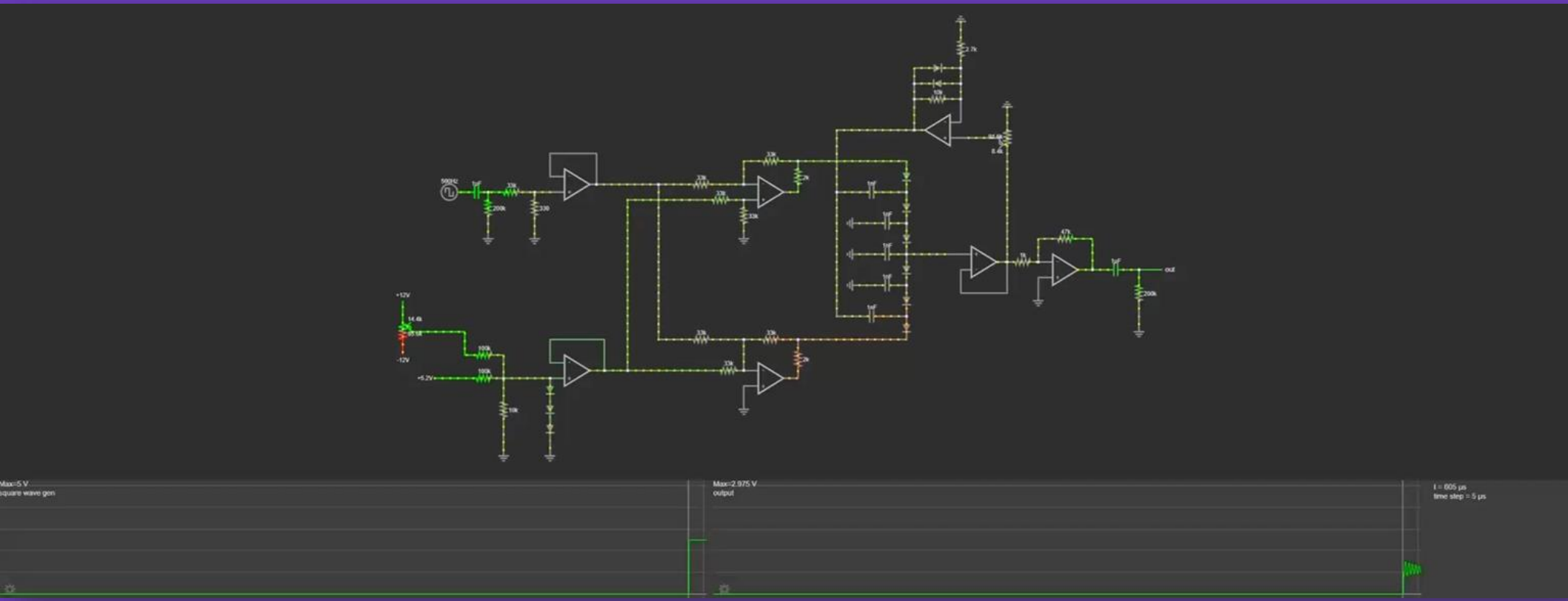
Output Stage (Multiplier and AC Coupling)



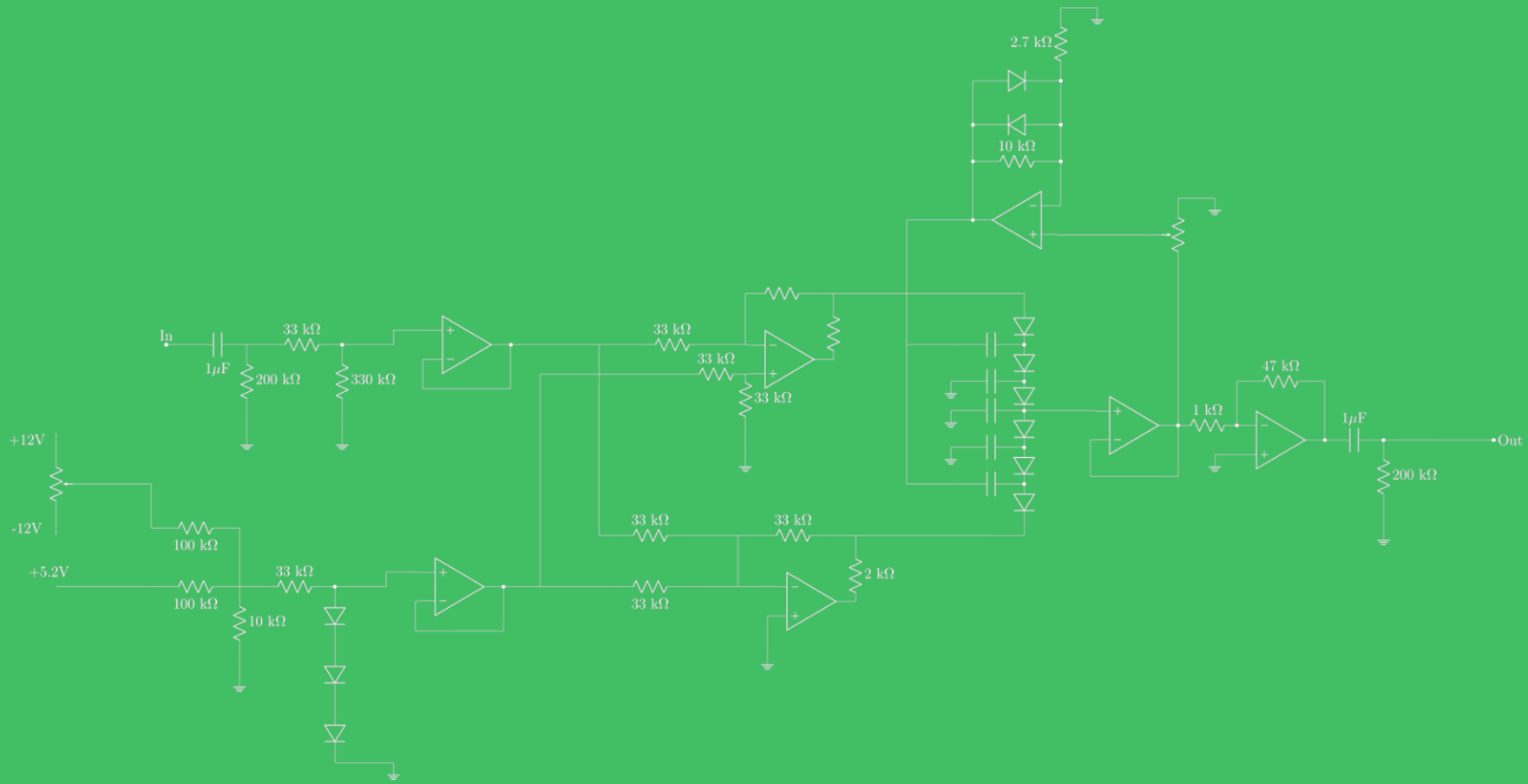
The Mess



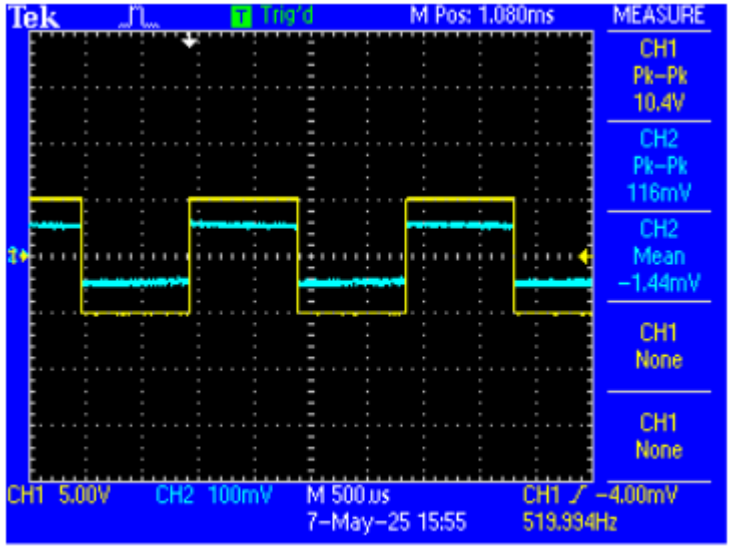
Simulation


500Hz
+12V
-12V
+5.2V
out
Max=5 V
square wave gen
Max=2.975 V
output
t = 605 µs
time step = 5 µs

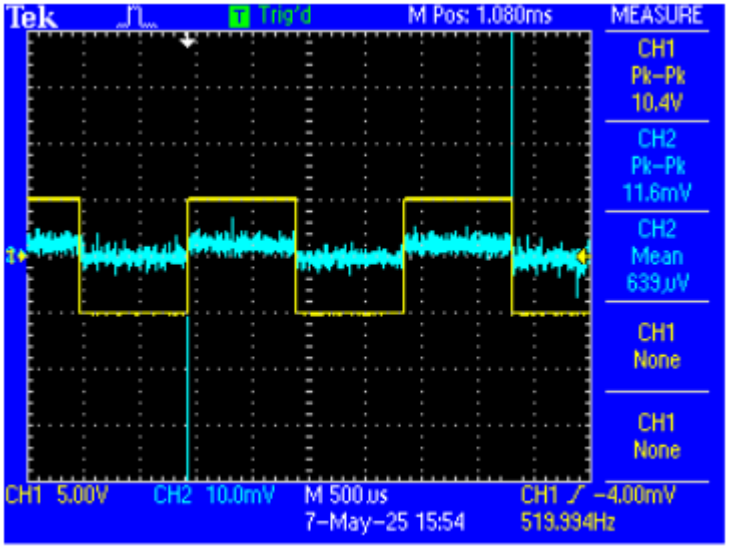
Characterization



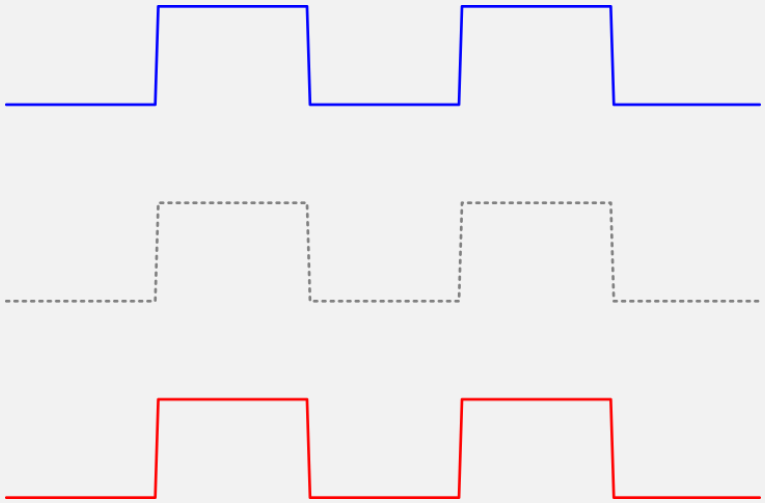
Characterization: F1

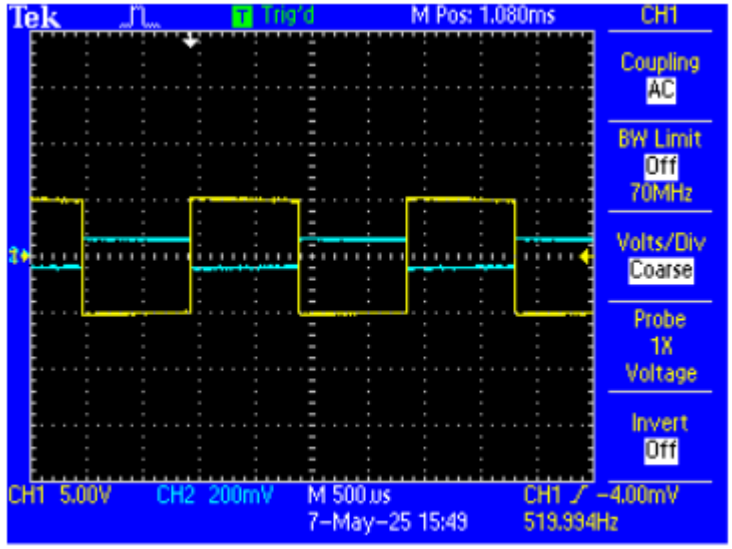


Characterization: F3

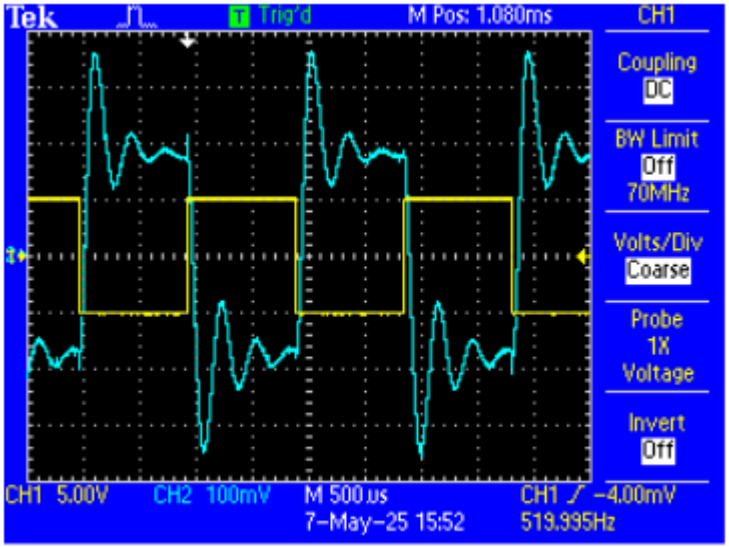


Characterization: Shifting Voltages (O2, O3)

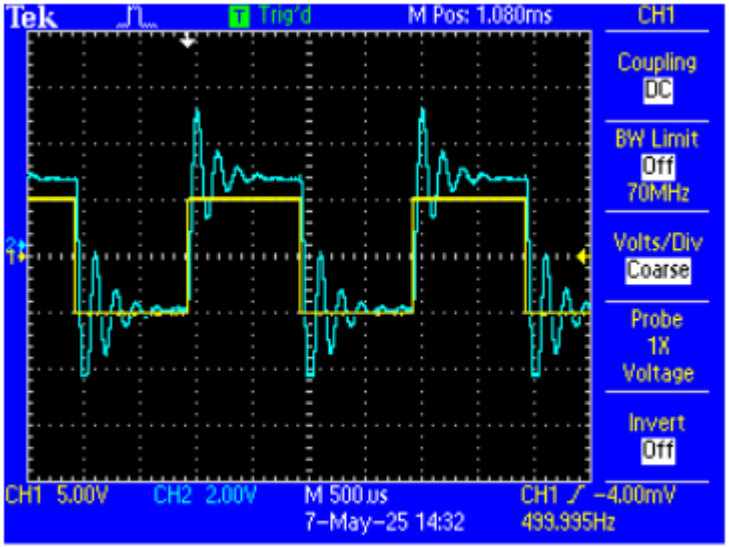




Characterization: O3



Characterization: Output



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Supplemental Slides

Image shown is a representation only. Exact specifications should be obtained from the product data sheet.

1N4148

DigiKey Part Number	1N4148FS-ND
Manufacturer	onsemi
Manufacturer Product Number	1N4148
Description	DIODE STANDARD 100V 200MA DO35
Manufacturer Standard Lead Time	22 Weeks
Customer Reference	
Detailed Description	Diode 100 V 200mA Through Hole DO-35
Datasheet	Datasheet
EDA/CAD Models	1N4148 Models