

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

Grant Saggars<sup>1</sup> Moritz Klein<sup>2</sup>



# Topics to Cover

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



# Background: Sounds and Signals

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**The fully professional, digitally programmable, MIDI-interfaceable, surprisingly portable, unbelievably affordable Korg Poly 800.**



## KORG POLY 800

The new Korg® Poly 800 literally creates an entirely new category of professional synthesizers. Korg's constant refinement of synthesizer technology allows us to bring you a totally programmable polyphonic synthesizer, loaded with sounds and features, that sells for less than \$800.

**8 VOICES  
PROFESSIONAL SOUNDS**  
The Poly 800's unique architec-

professional would expect.

In fact, the Poly 800's powerful layering mode can give you two different sounds for each note. This means even thicker textures and more complex voicings.

**64 PROGRAMS**

offer only four). This feature is

a significant improvement over common ADSR-type envelopes, allowing more expressive control.

Your patches can be saved in the Poly 800's memory and off-loaded to tape in 14 seconds. You can

A Noise Generator with individual articulation circuitry lends realism to sounds such as flute, other wind instruments and dramatic special effects.

An on-board programmable Stereo Chorus adds extra depth

**13 LBS  
THE MOST PORTABLE  
POLYPHONIC**



All of the versatility offered by the Korg Poly 800 fits into an amazingly light and

And the headphone jack lets you practice anywhere.

If you want to expand your keyboard set-up or you've been held back by the high price of polyphonic synthesizers until now, investigate the unbelievably affordable Korg Poly 800 at your local Korg dealer. Or send \$3.00 (check or money order) to Unicord, 89 Frost St., Westbury, New York 11590 for a Poly 800 demo record.

**THE  
ULTIMATE  
SOUND OF MOOG.**

The sound of the Memorymoog in a polyphonic programmable instrument. The Memorymoog, from Moog, 3 oscillators per voice through the patented Moog filter, 75 programs with 10 program channels, programmable foot pedals, return-to-zero or unconditional contours and extensive voice modulation options give the Memorymoog more sound and musical expressiveness than any instrument of its kind.

Only Moog engineering could create this instrument; only Moog manufacturing could produce it at such an affordable price.

The Memorymoog. From Moog. **memorymoog**

The people who started it all.

Moog Music Inc., 2500 Walden Avenue, Buffalo, NY 14226  
Moog Music, Waalhaven 222, 46, Rotterdam 3388 HJ, Holland The Netherlands

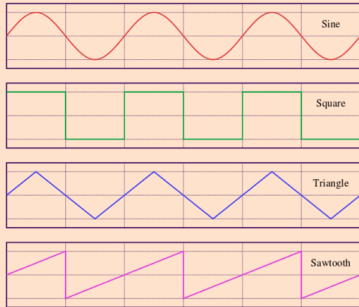
We take a lot of ideas from these guys!



# Basic Operation of a Synthesizer

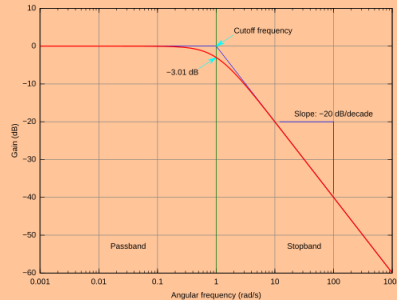
## 1. Make a signal

Signal Generators!



## 2. “Shape” a signal

Filters!



## 3. Output the sound

Speakers!





# Design Considerations

- V

- I



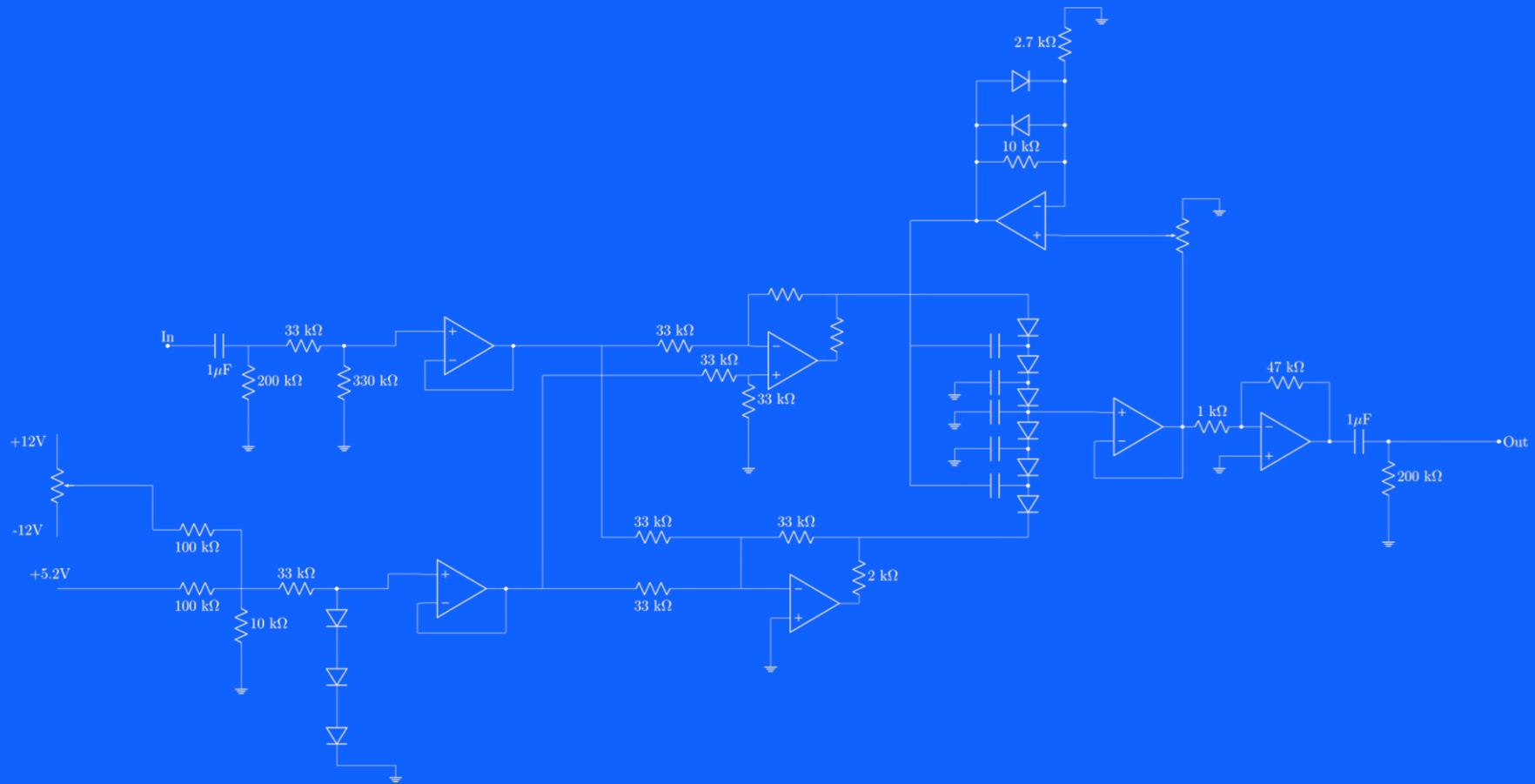


# Design Considerations

- **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

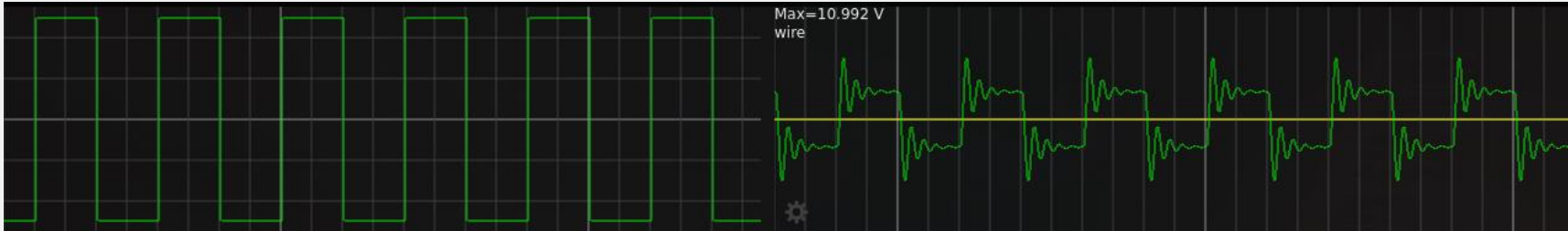
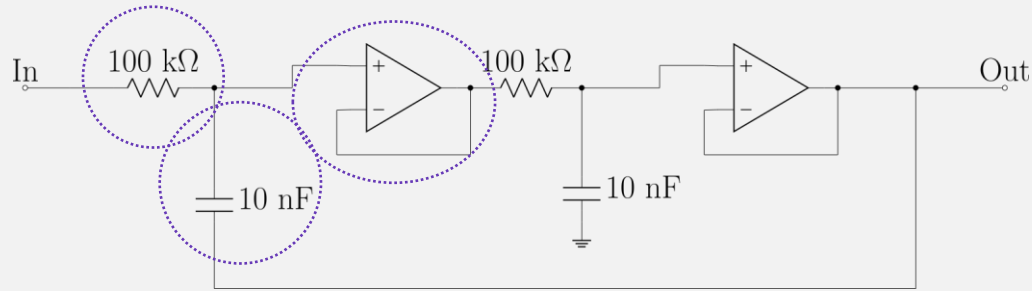


# Outcome...





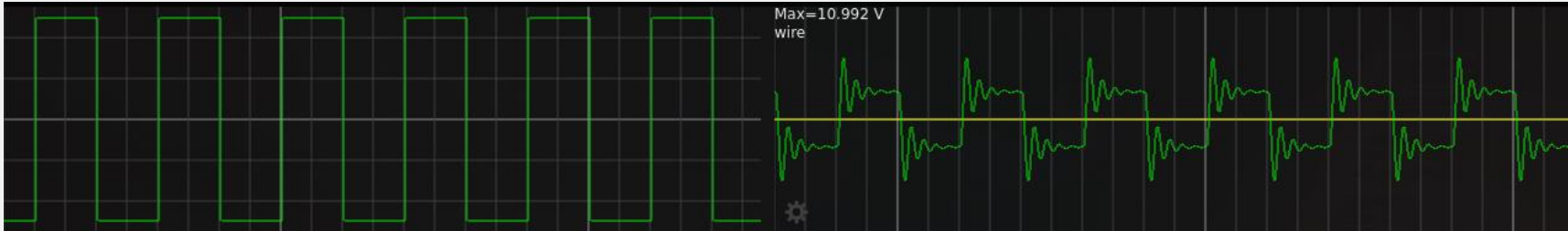
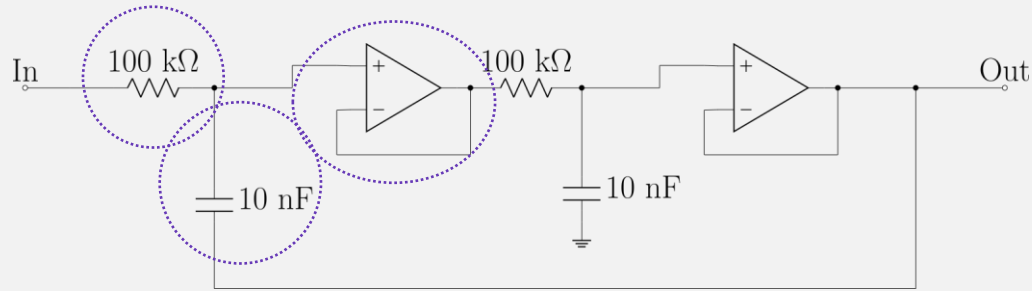
# Basic Resonant Filters



Interesting, but not very useful yet!



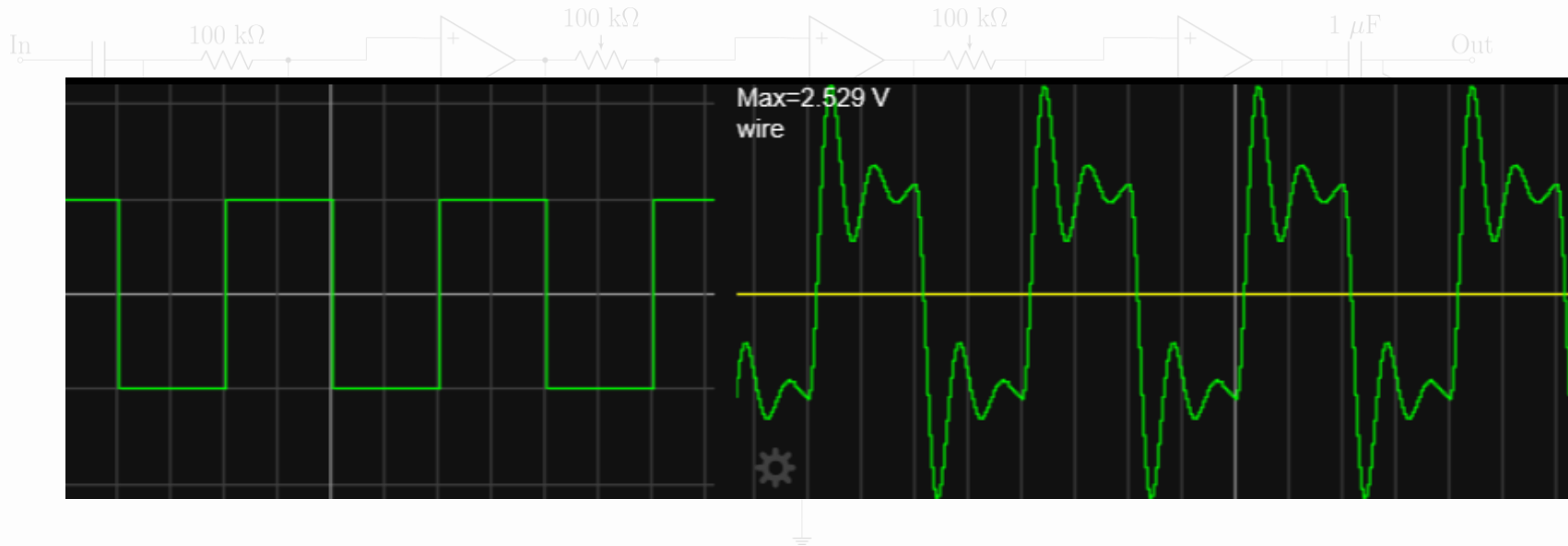
# Basic Resonant Filters



Interesting, but not very useful yet!



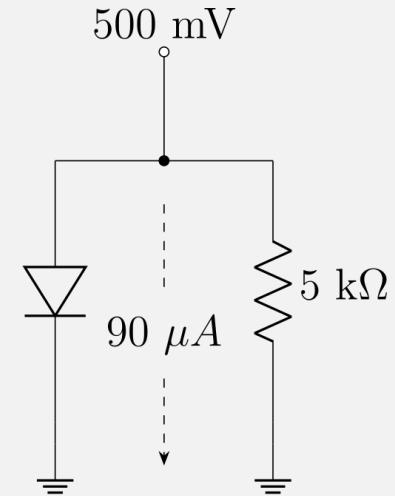
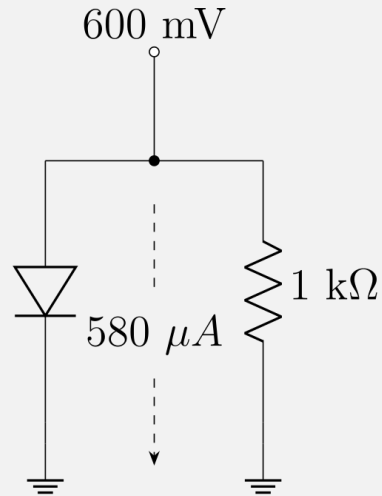
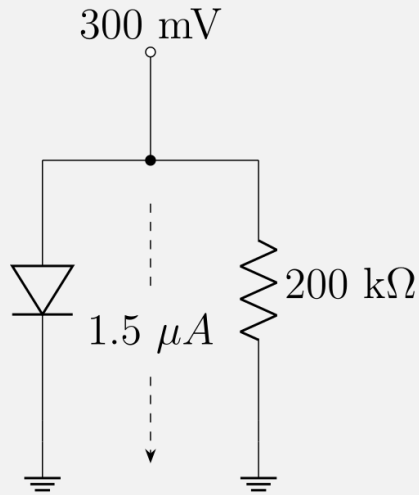
# The Fully Resonant Low Pass



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

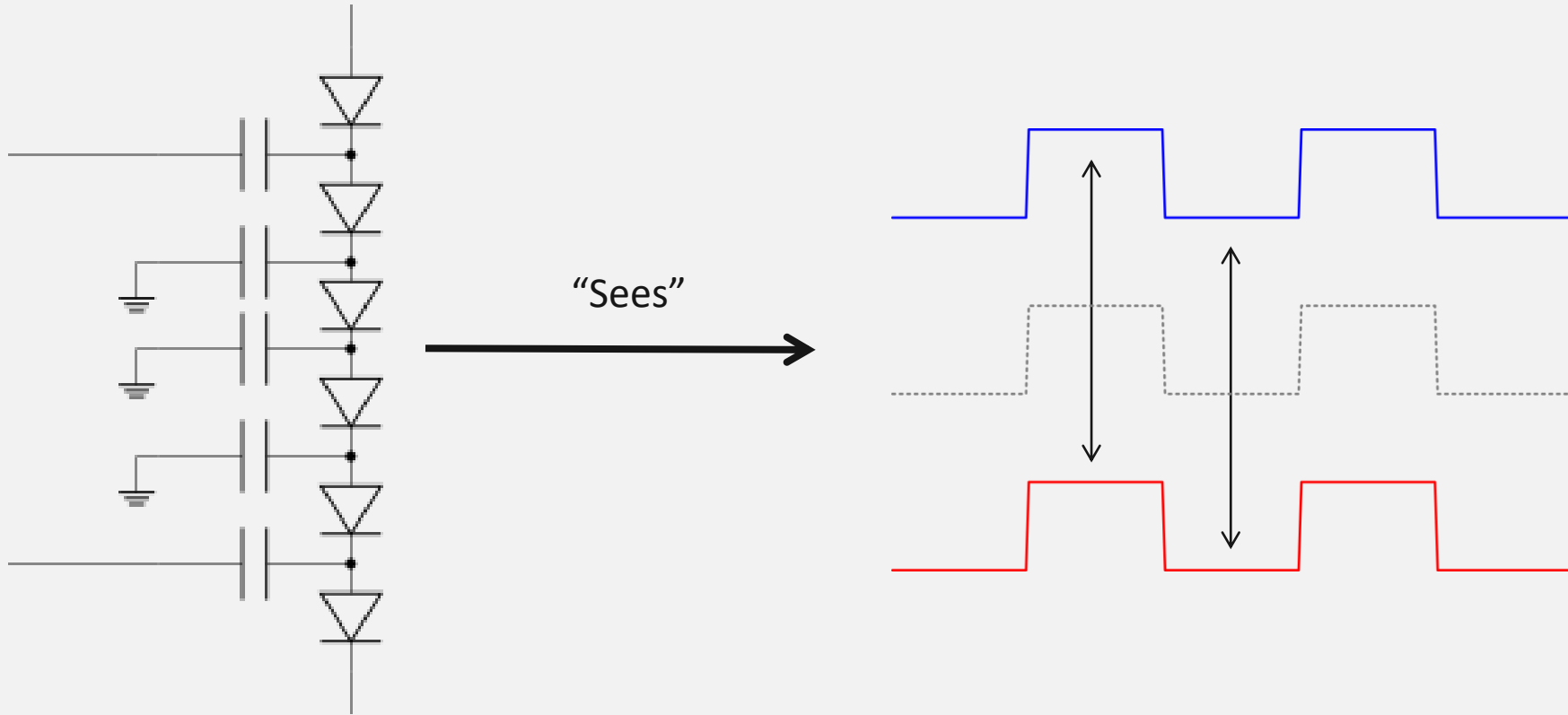


# Diodes as Voltage Controlled Resistors



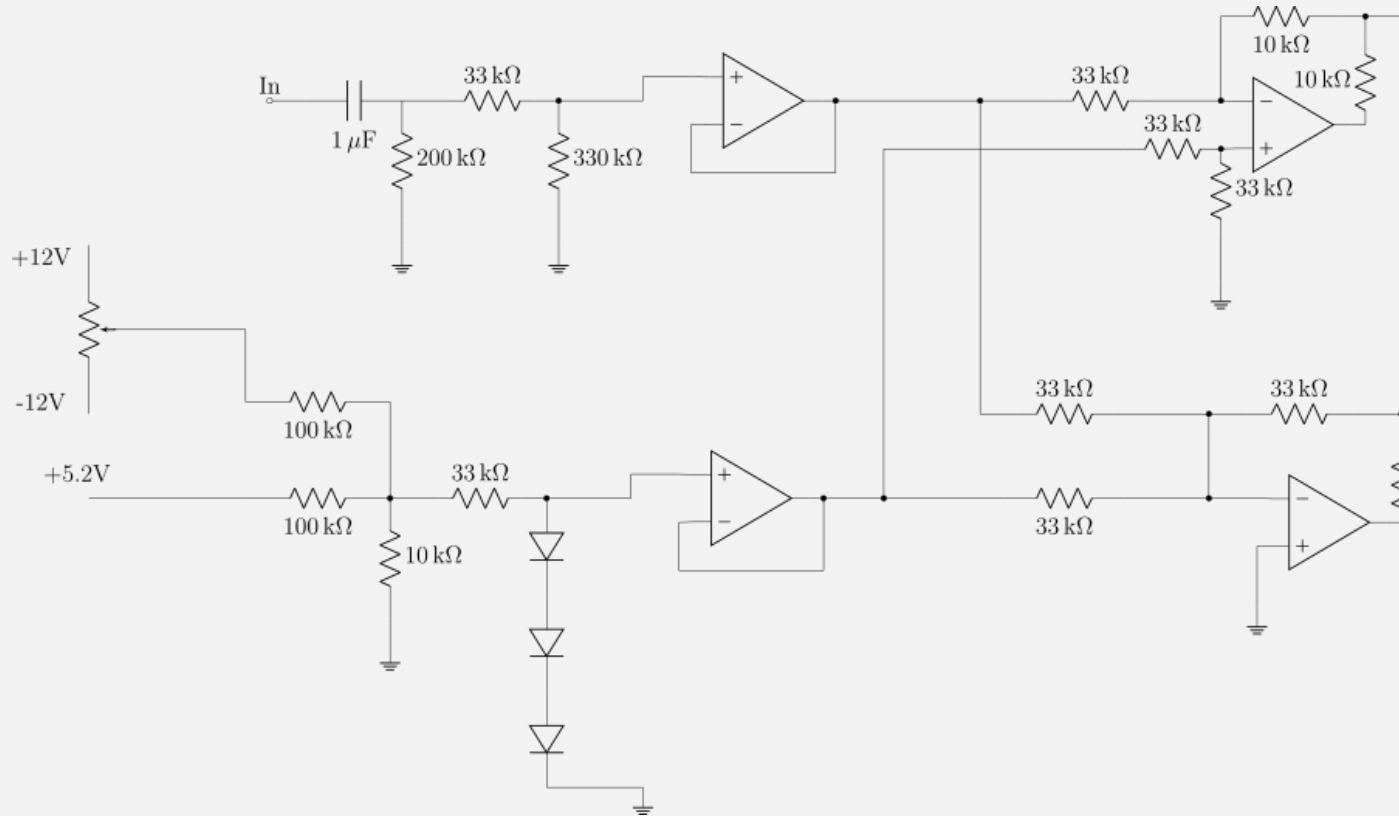


# The Multi-Pole Diode Ladder





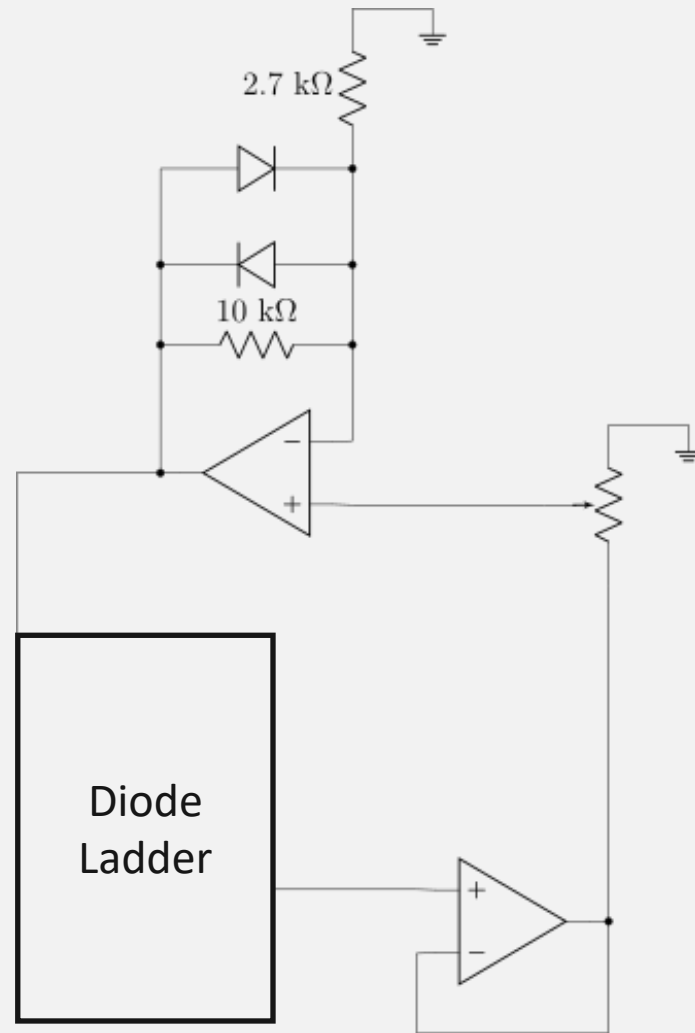
# Input Stage and Driver





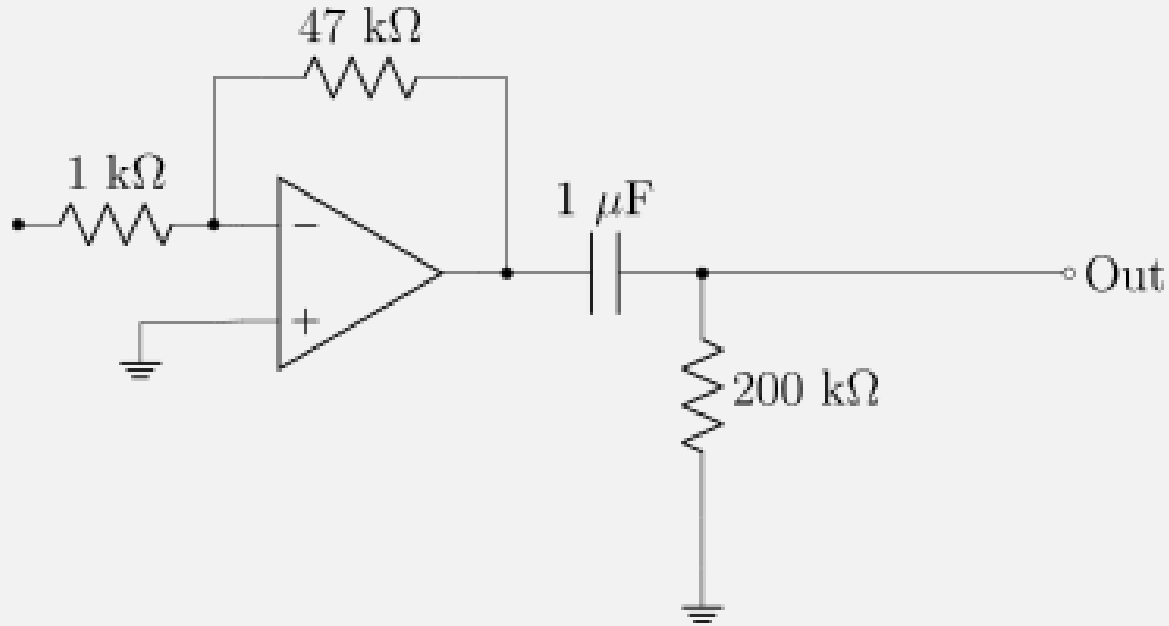
# Resonance

- 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!



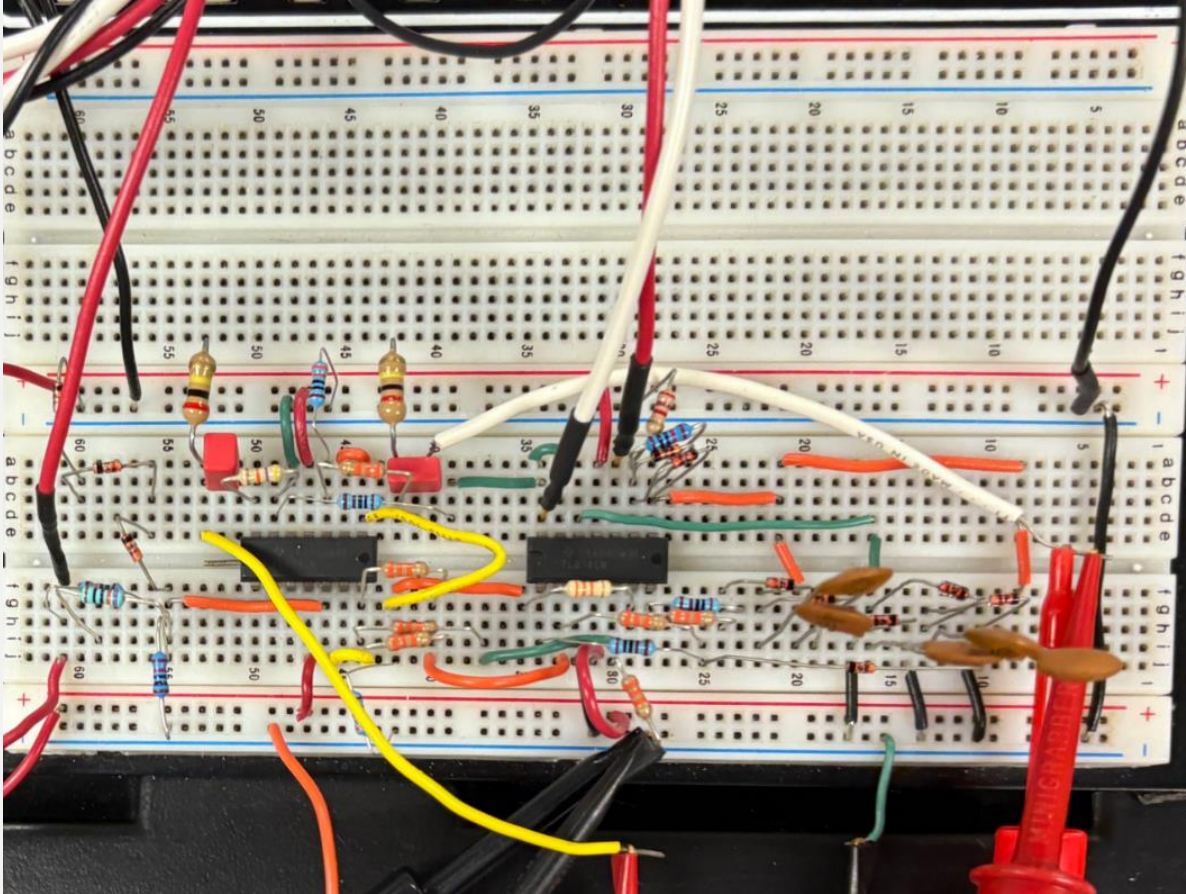


# Output Stage (Multiplier and AC Coupling)



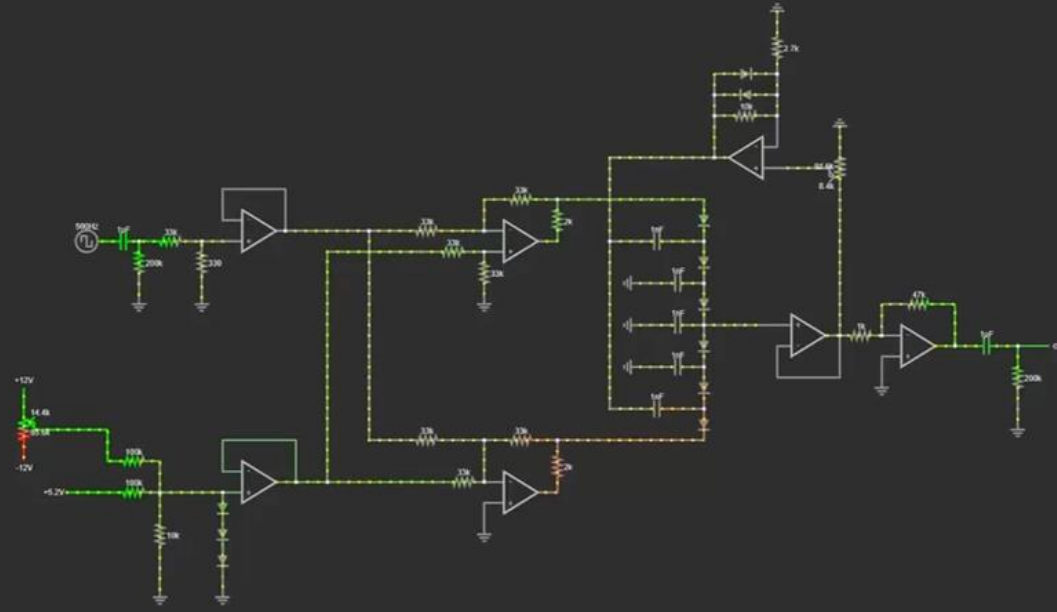


# The Mess





# Simulation



Max: 5 V  
square wave gen

Max: 2.975 V  
output

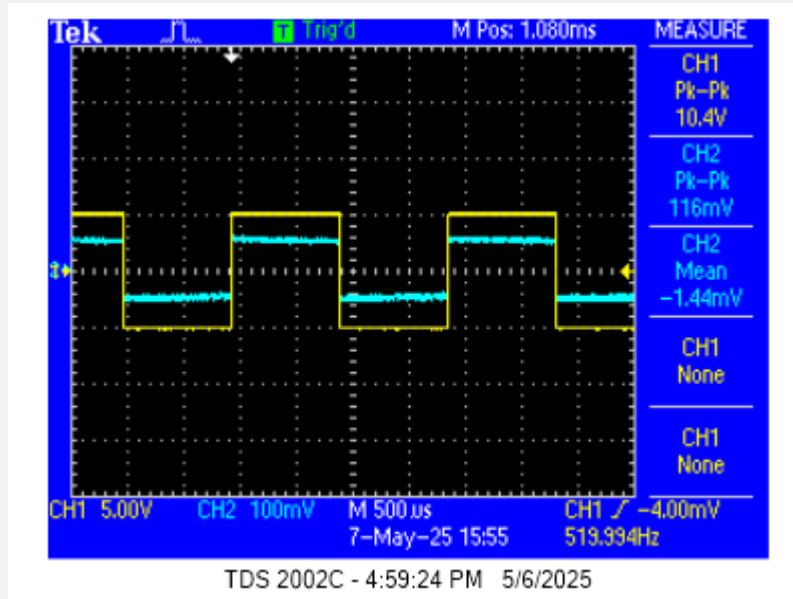
t = 605 ps  
time step = 5 ps



## TK

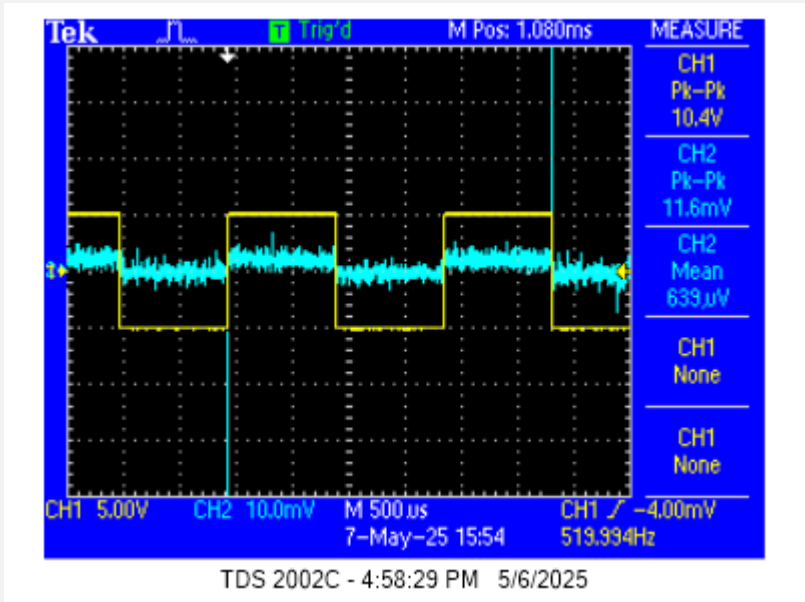


# Characterization: F1



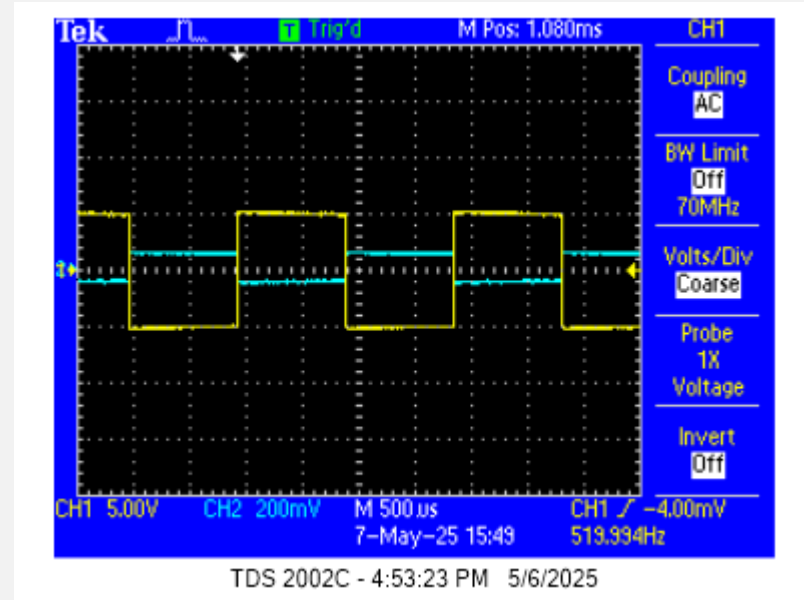
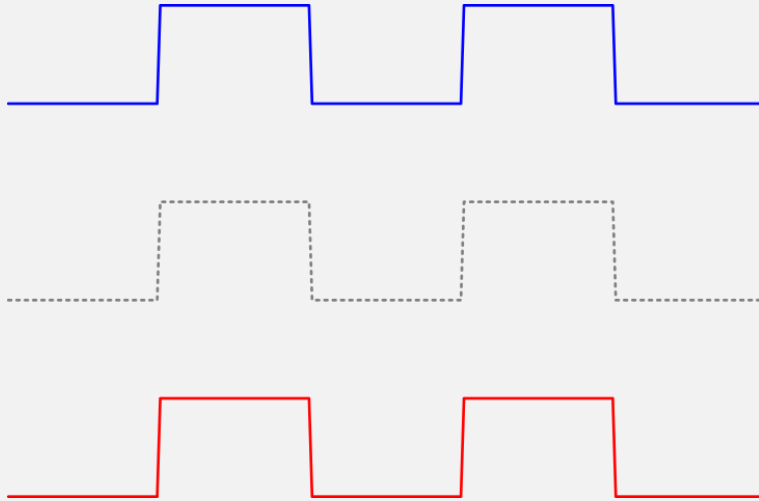


# Characterization: F3



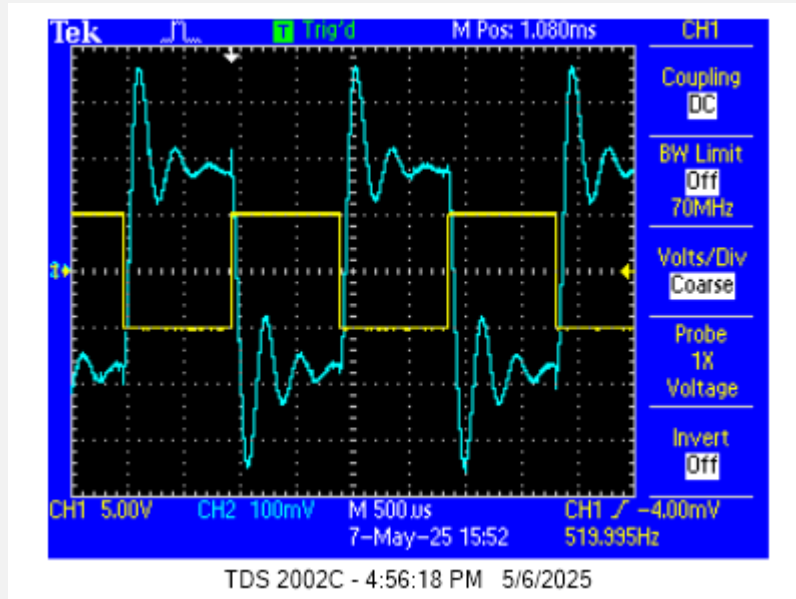


# Characterization: Shifting Voltages (02, 03)



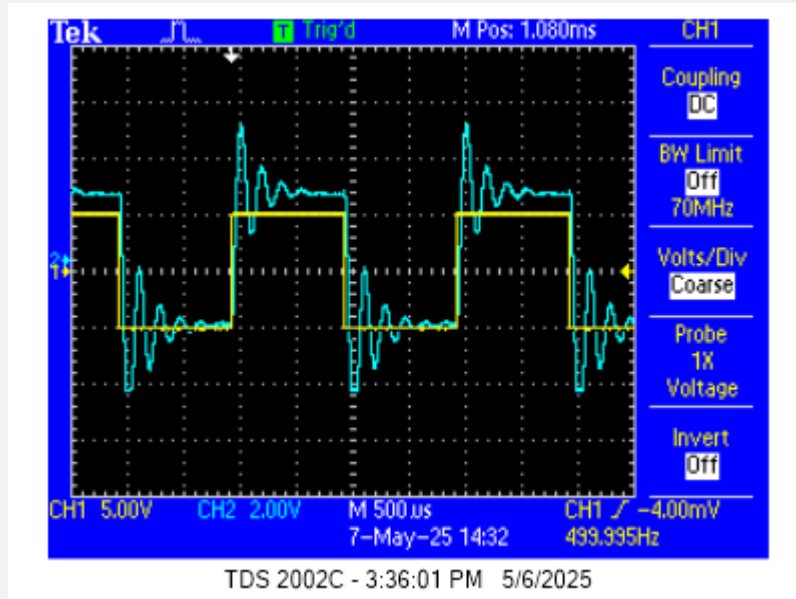


# Characterization: 03





# 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	<a href="#">onsemi</a>
Manufacturer Product Number	1N4148
Description	DIODE STANDARD 100V 200MA DO35
Manufacturer Standard Lead Time	22 Weeks
Customer Reference	<input type="text"/>
Detailed Description	Diode 100 V 200mA Through Hole DO-35
Datasheet	 <a href="#">Datasheet</a>
EDA/CAD Models	<a href="#">1N4148 Models</a>

