



# UPS WAVEFORMS

THE GOOD, THE BAD AND THE UGLY

WILLEM AC0KQ

NERDFEST 2023

# GENERAC SYNERGY 20KW GENERATOR

- All house standby generator
  - Propane motor
  - DC generator, AC inverter
- Throttles motor to match load
  - AC inverter needed for 60Hz
- *but some UPS devices freak out!!!*





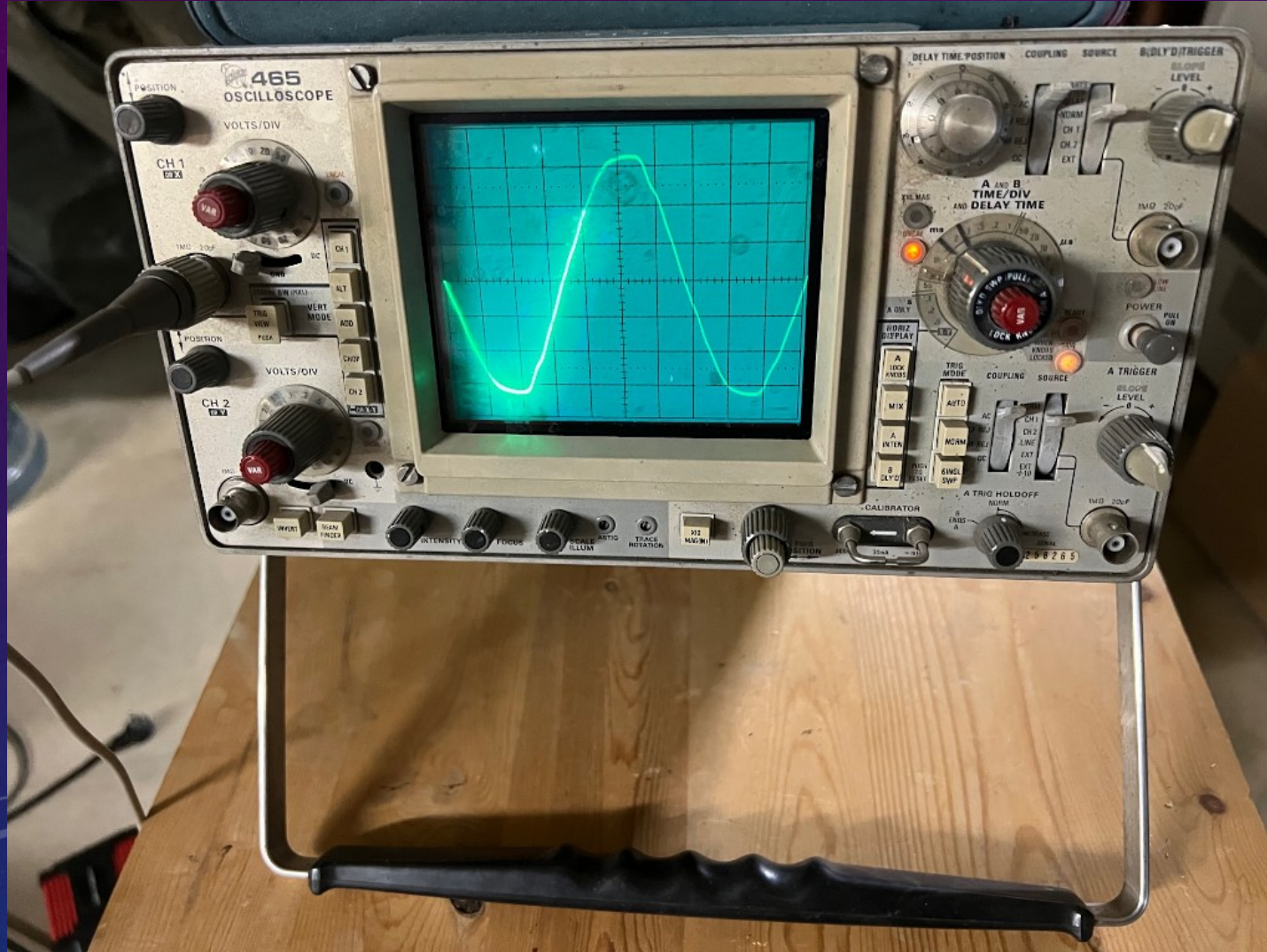
# WHAT DOES THE WAVEFORM LOOK LIKE?

- It is a "modified sine wave"
  - Higher end UPS units do just fine
  - Inexpensive ones freak out
- Why??????





# TEST SETUP

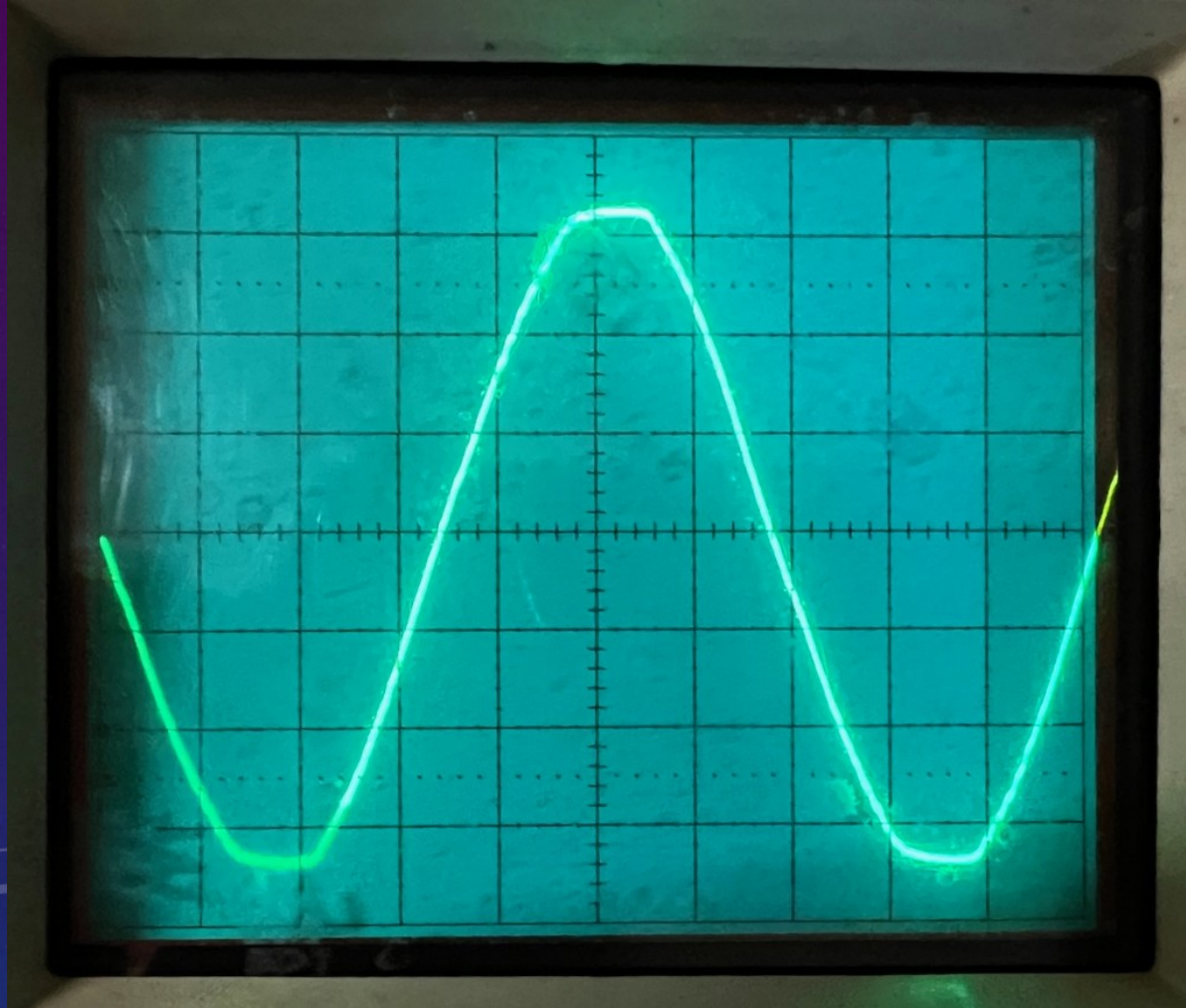


- Tektronix 465  
with 10x probe  
I did clean the screen but some  
of that gunk is just permanent





# IREA/COOP UTILITY POWER

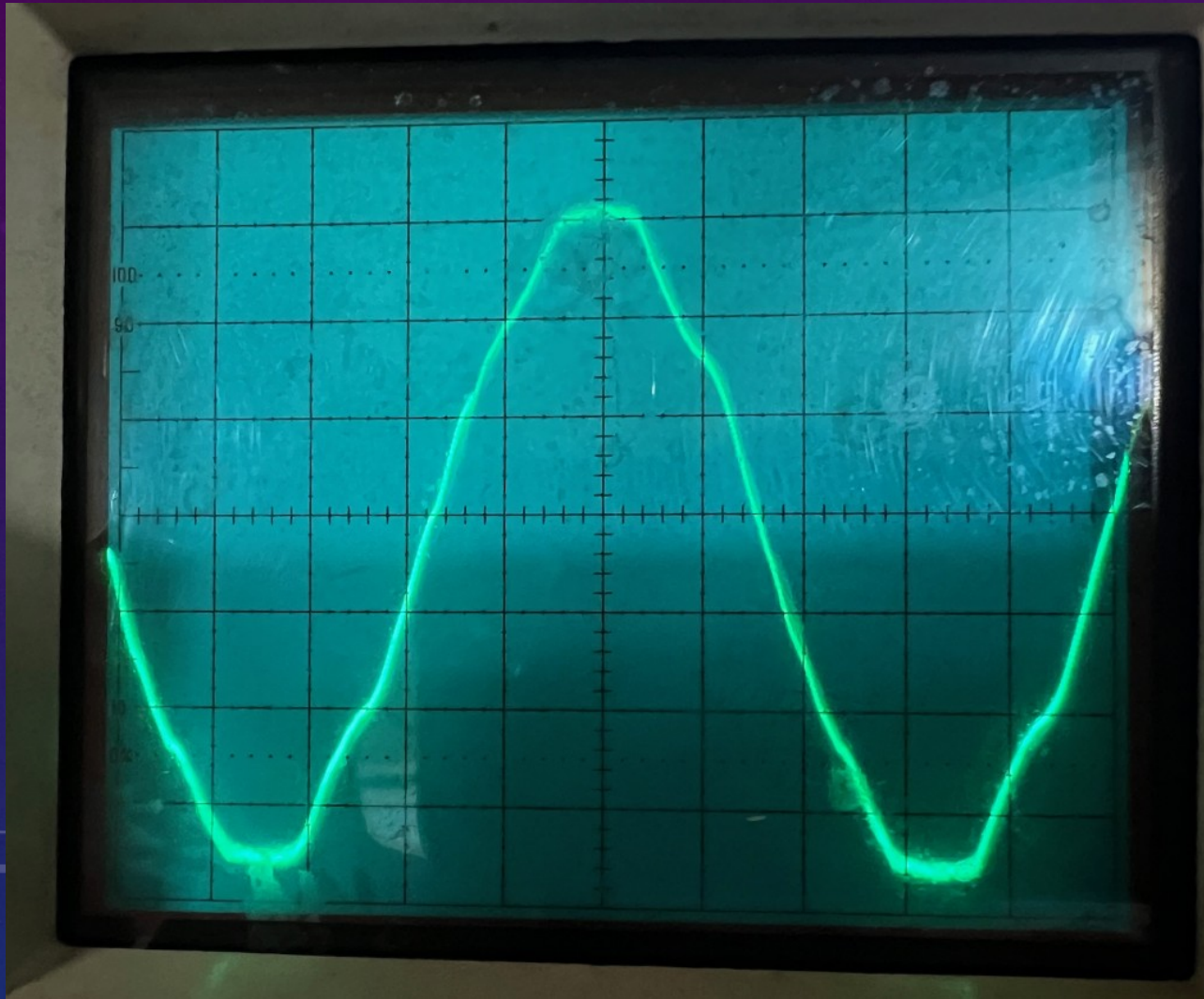


- Not a perfect sine wave, but pretty close





# GENERAC SYNERGY 20KW

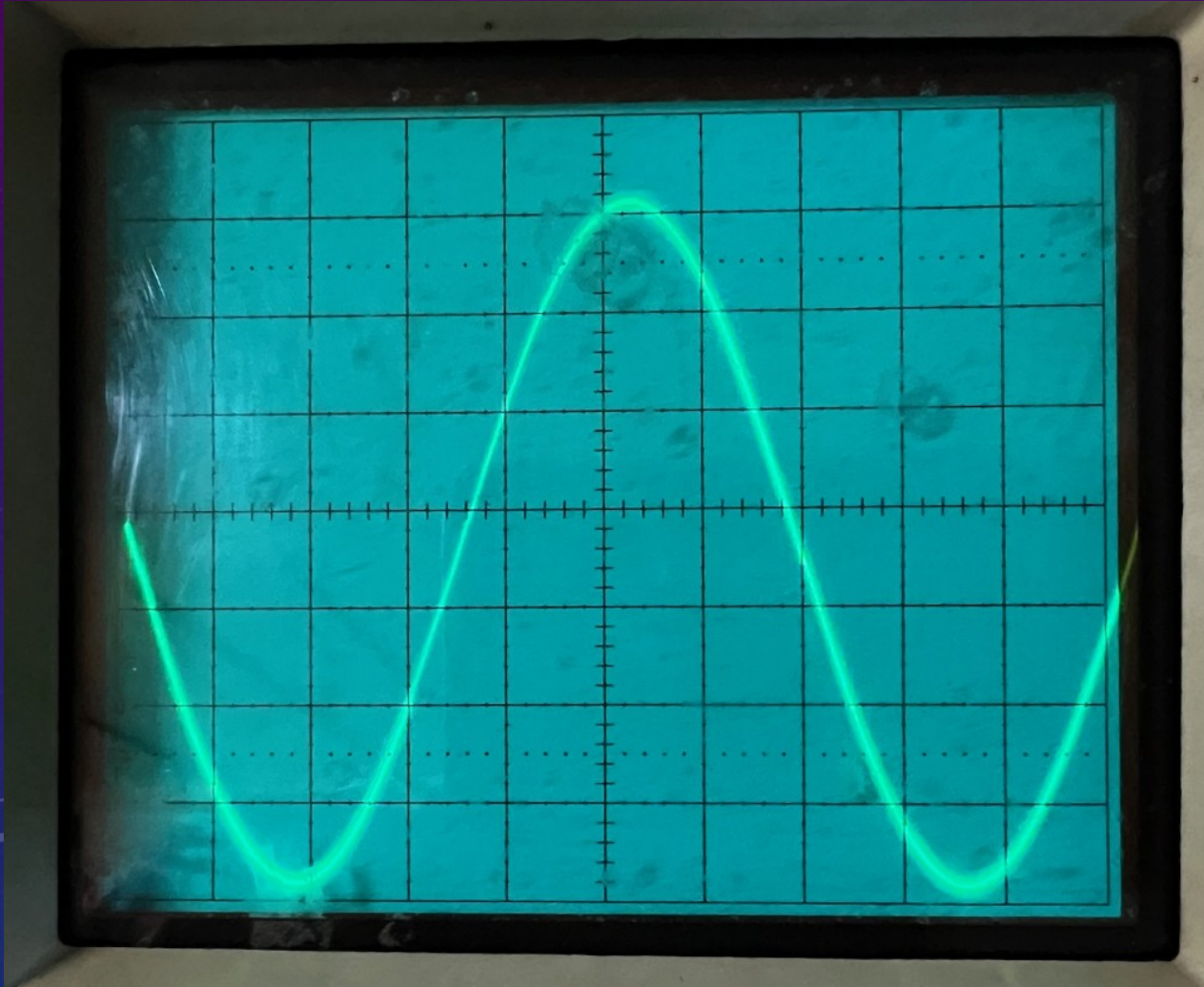


- Modified sine wave, uneven slopes





# GENERAC IQ2000 GENERATOR



- Nice since wave, but has some QRM on HF



# HOW DO YOU MAKE 60HZ AC FROM DC?

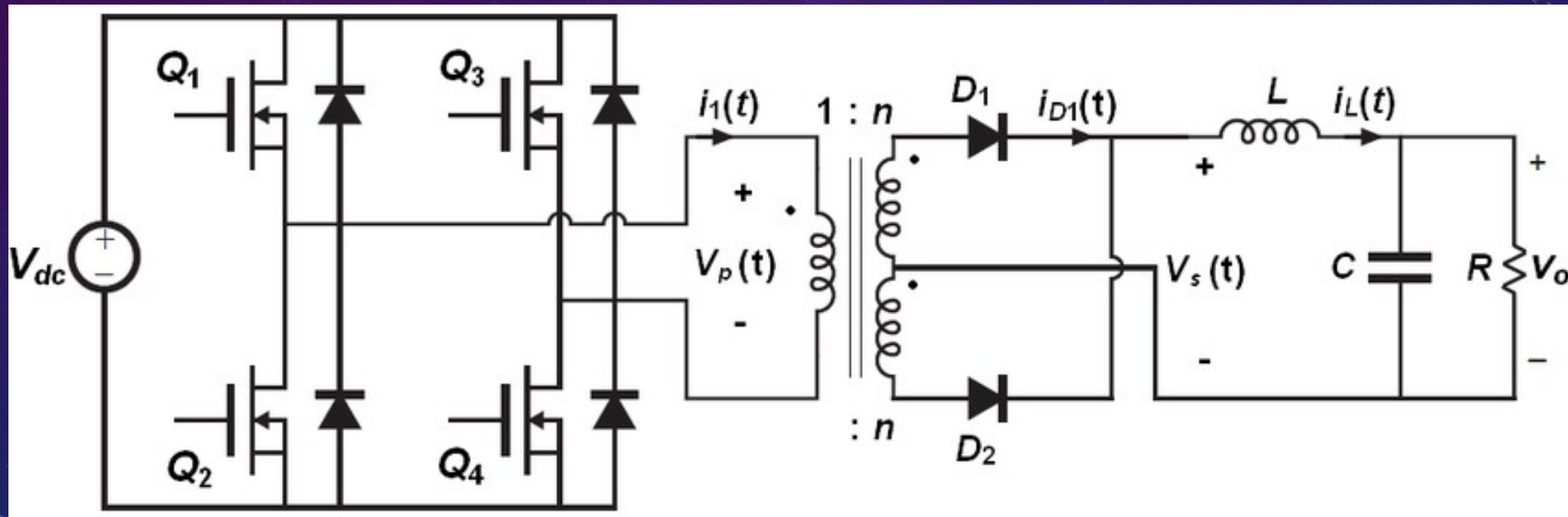
- 60Hz oscillator feeding BIG transformer
- kHz oscillator feeding small transformer rectified to make  $\sim 200\text{V}$  DC, then
  - use SCR to chop it to AC and filter
  - use pulse width modulation and low pass filter to make AC





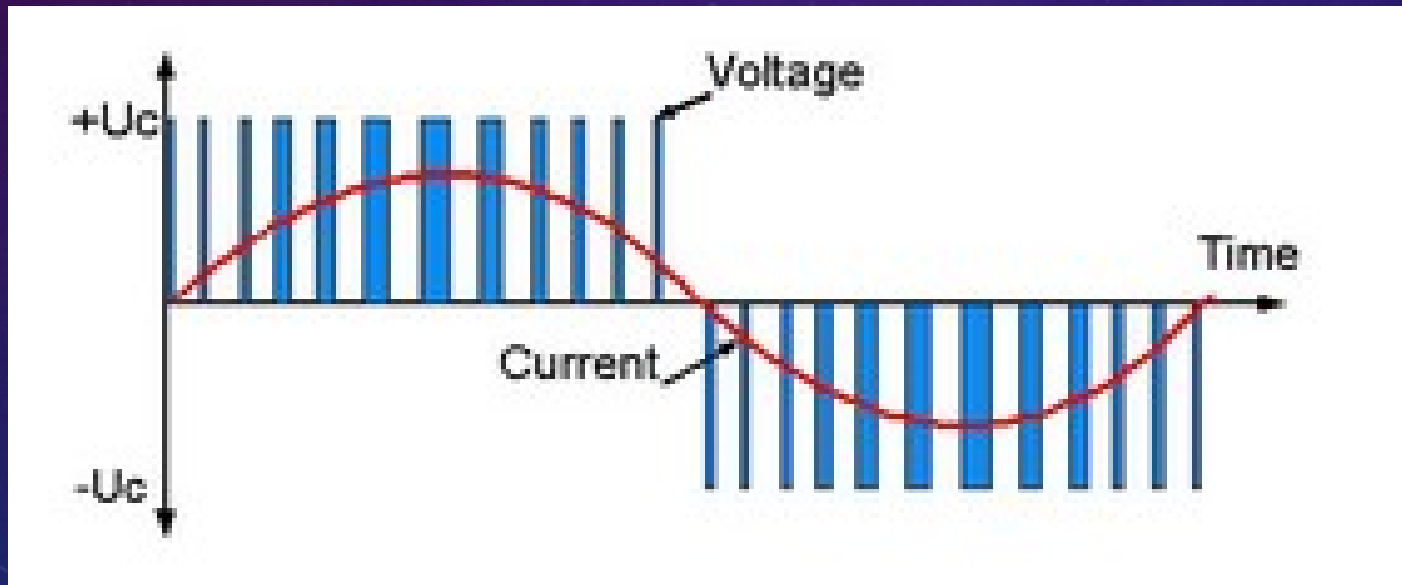
# HOW DO YOU MAKE HV DC?

Frequencies in the kHz range make the transformer smaller



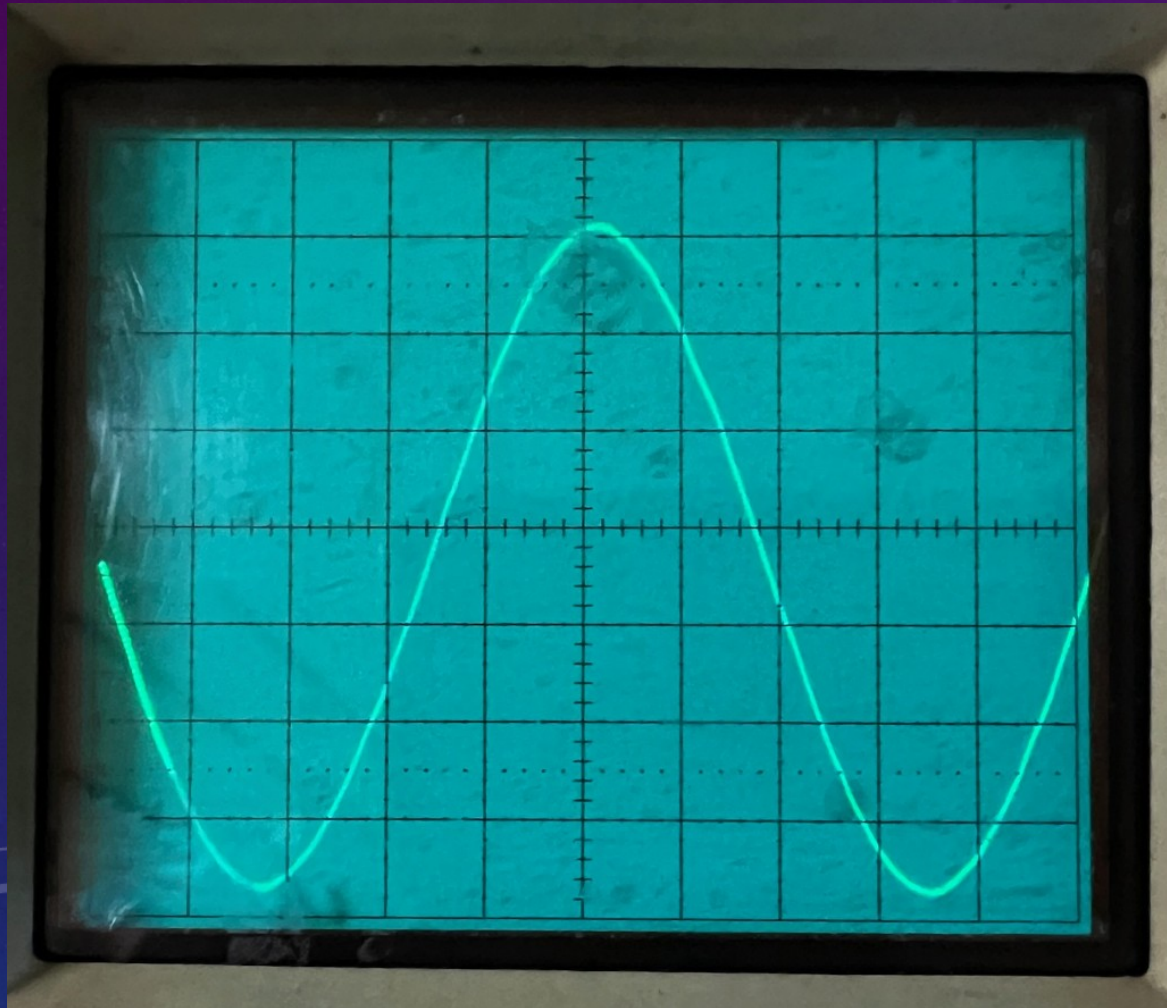
# HOW DO YOU MAKE 60HZ WITH PWM?

Requires high voltage, high current, fast switches like an SCR or power FET





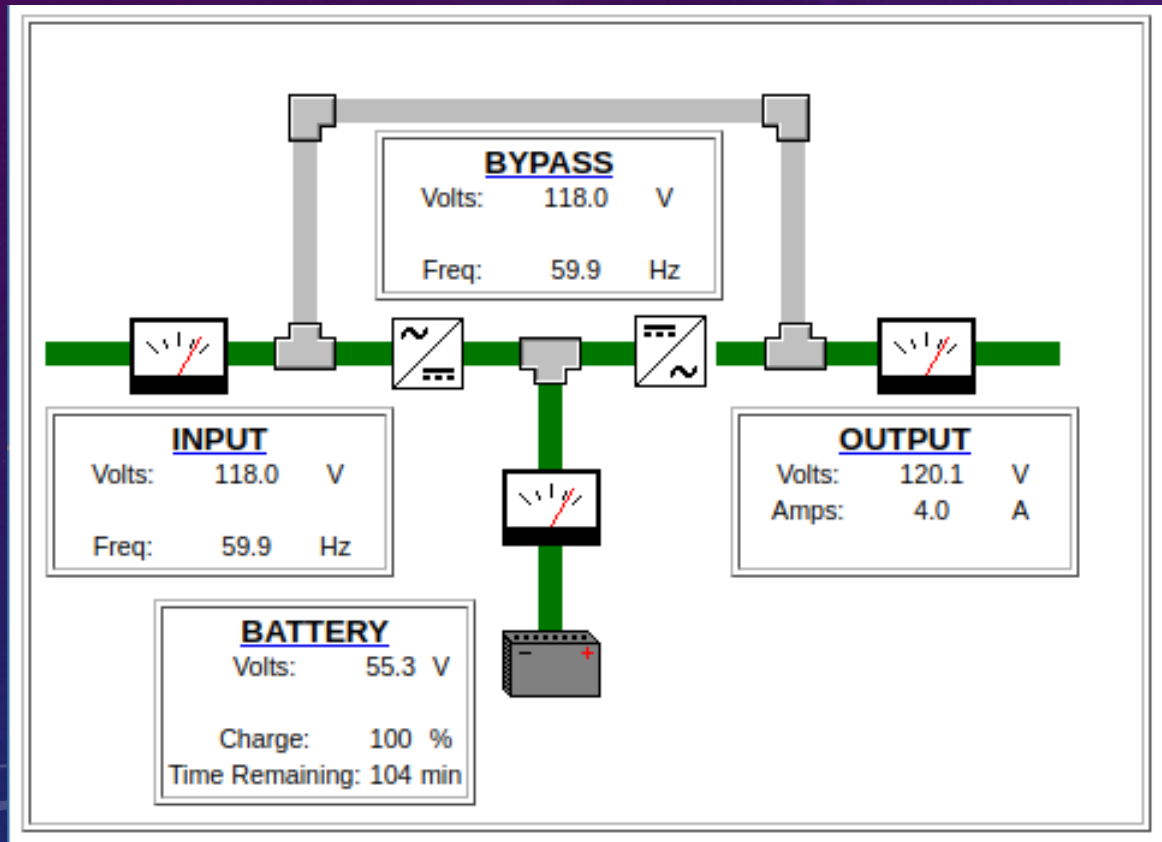
# LIEBERT GXT2-1500RT120



- Perfect sine wave, better than IREA on AC or battery



# LIEBERT RUNS IN ALWAYS ON MODE

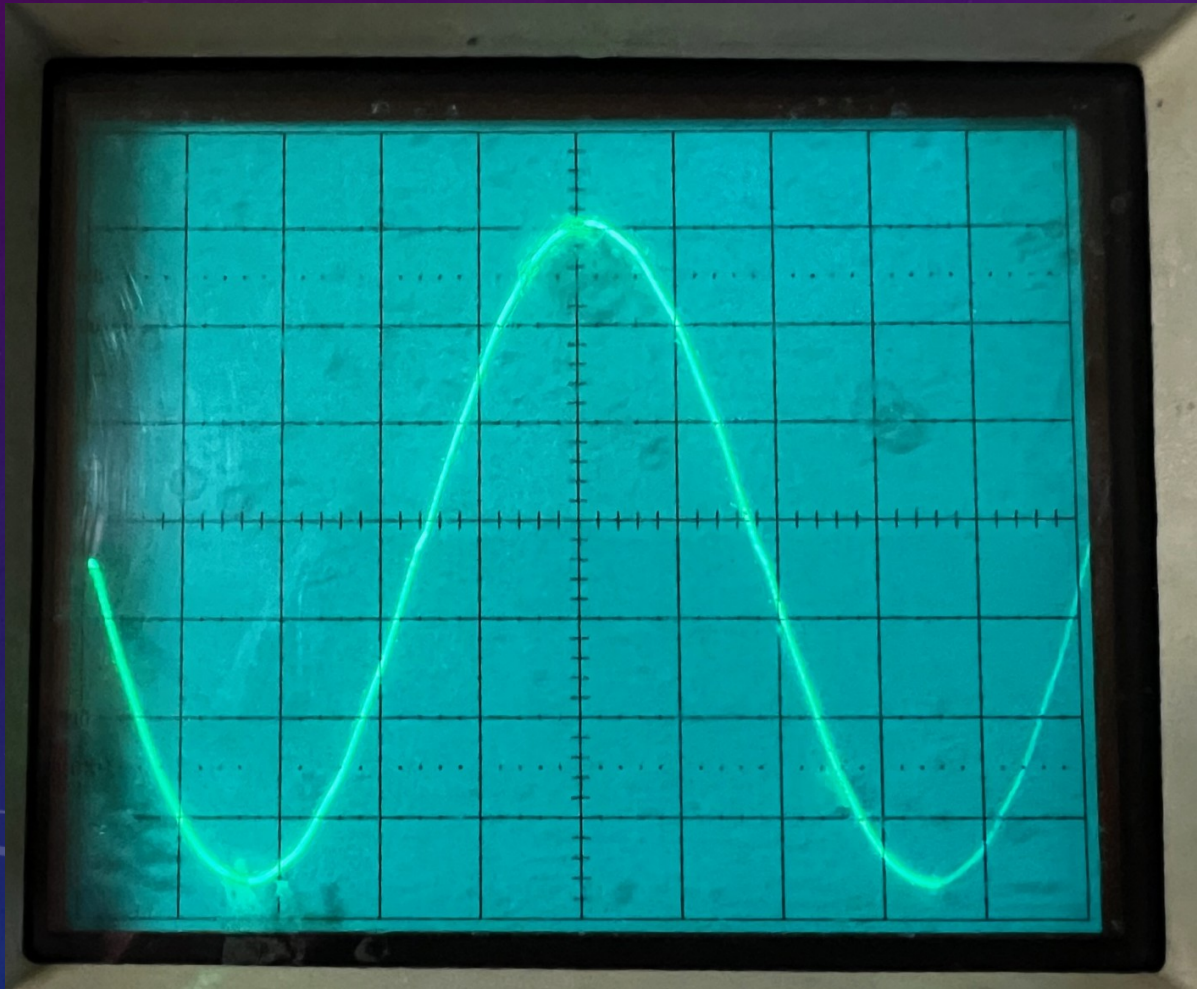


- Steady 120V on output prevents brownout





# APC SMARTUPS 1400 3U RACKMOUNT

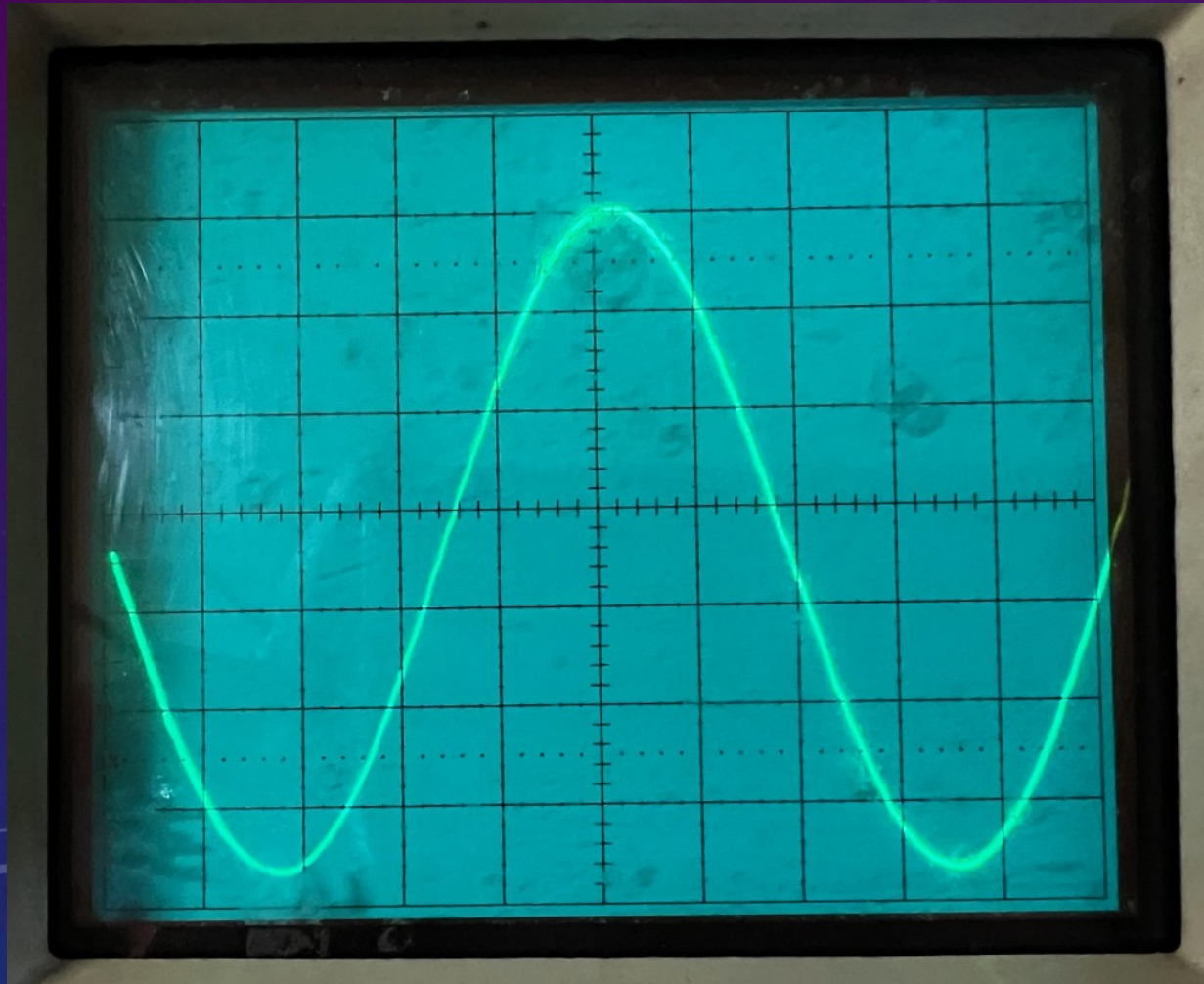


- Perfect sine wave on battery bypass on AC





# APC SMARTUPS 1400 2U RACKMOUNT

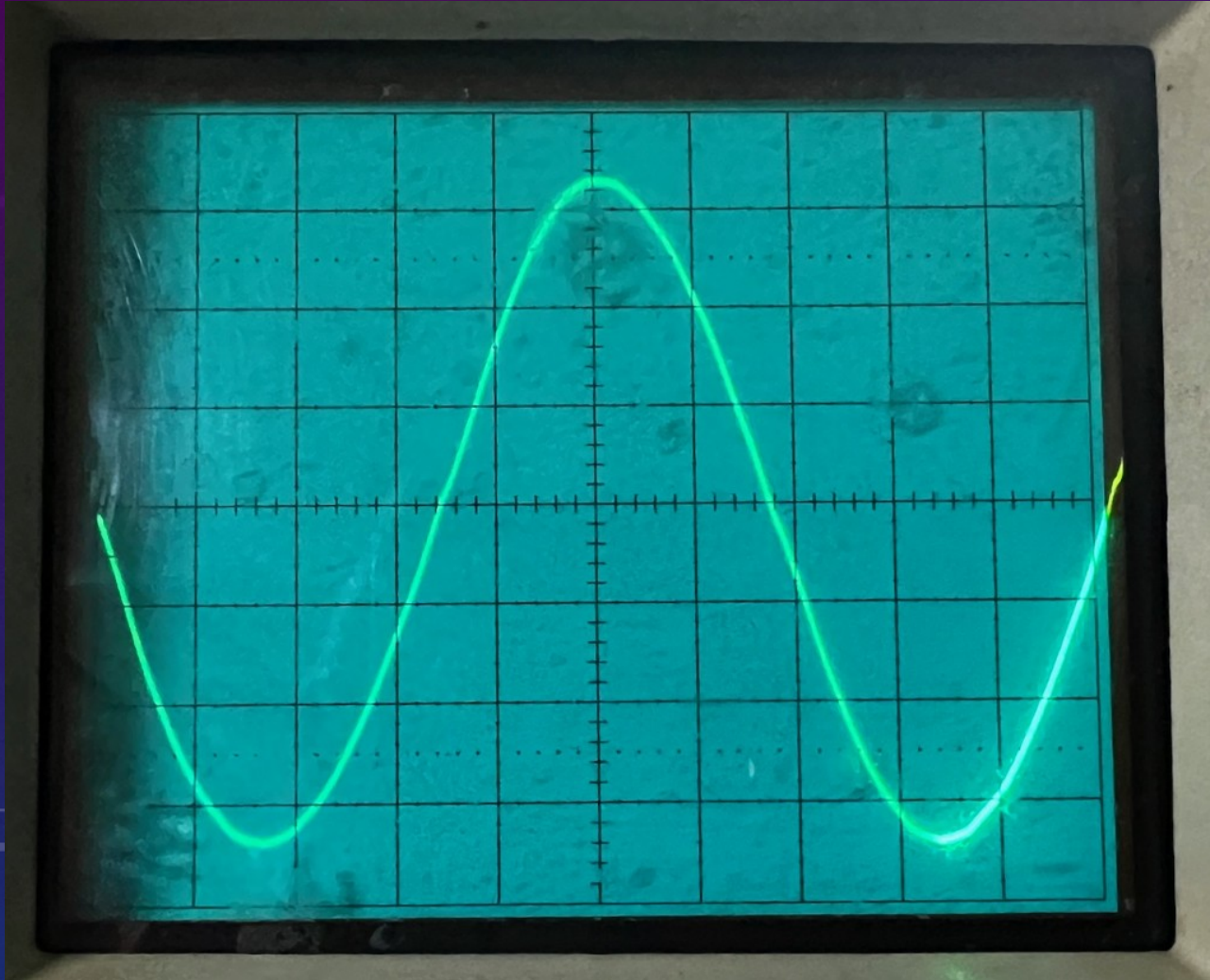


- Perfect sine wave on battery bypass on AC





# APC SMARTUPS 1500

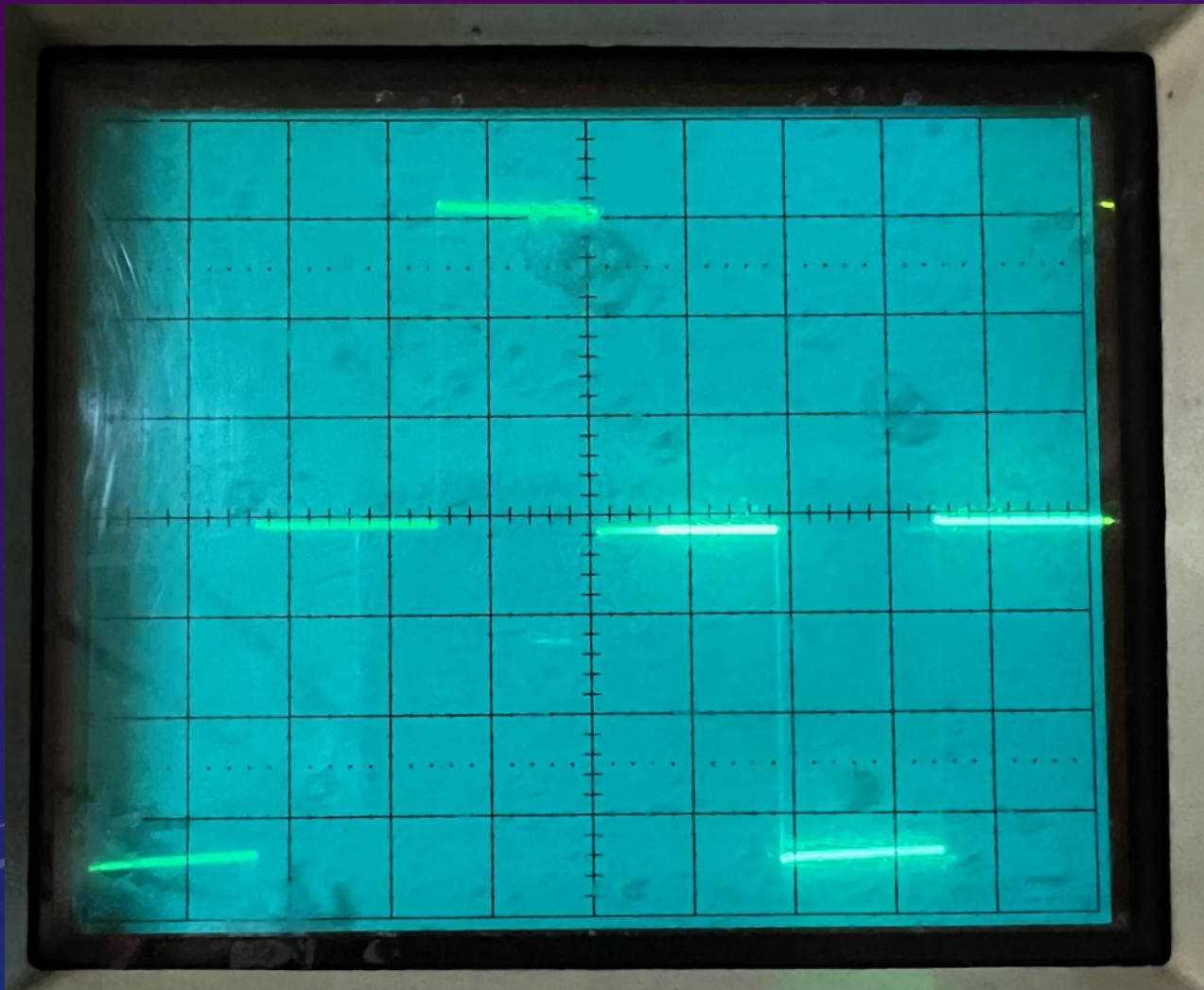


- Near perfect sine wave on battery bypass on AC





# HARBOR FREIGHT CEN-TECH 12V INVERTER

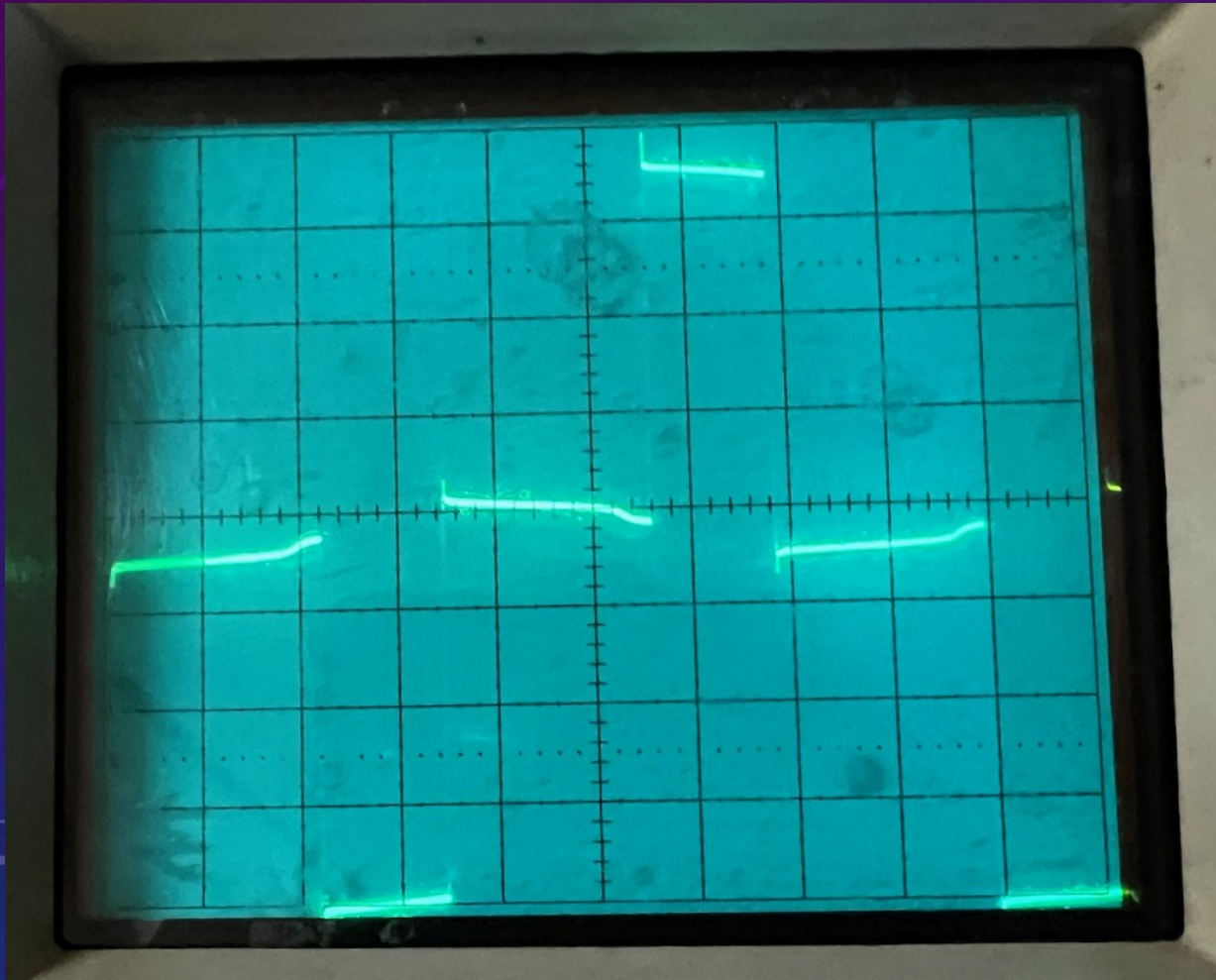


- A pretty nice square wave, assuming that's what you wanted





# APC BACKUPS 350 ES

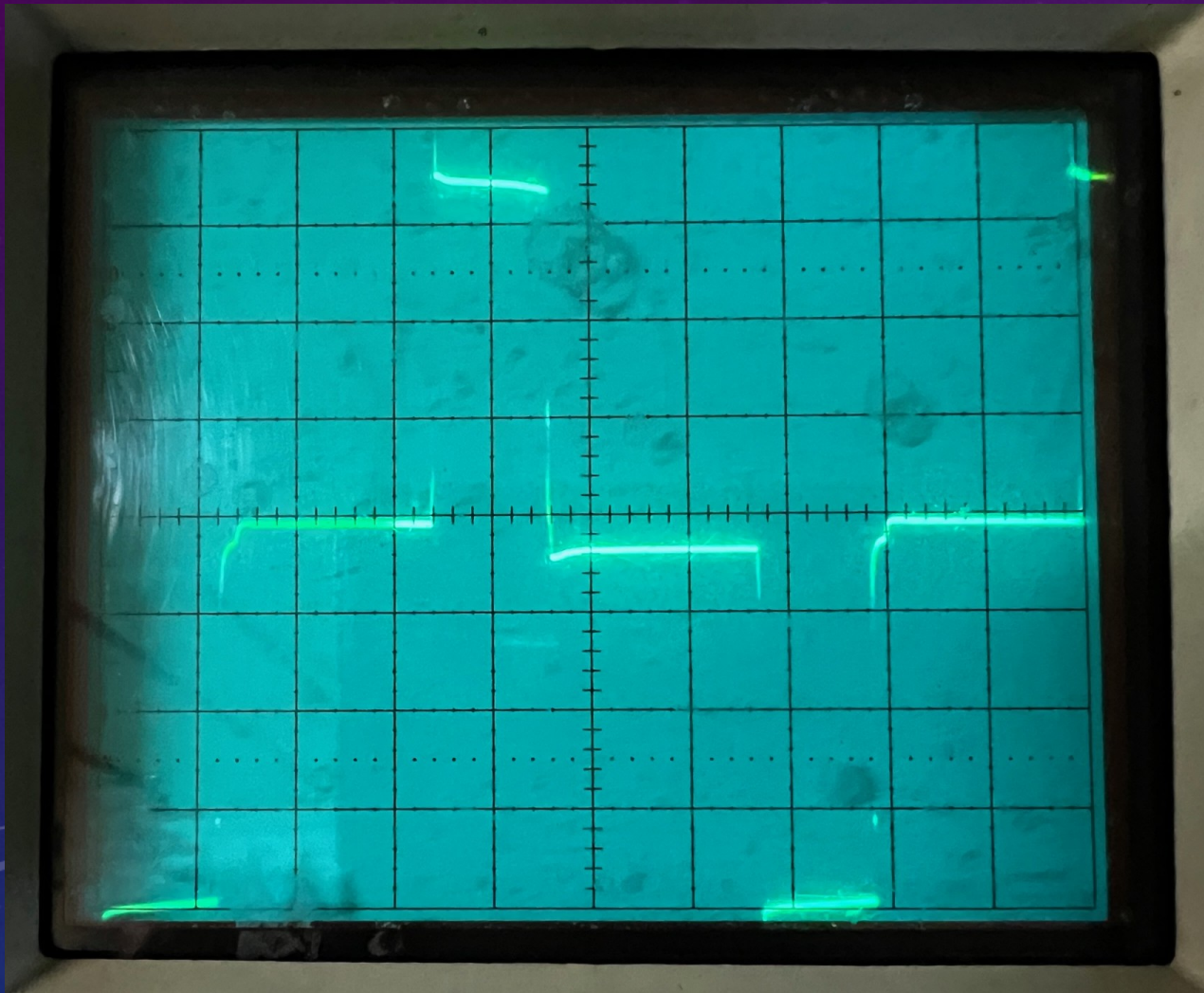


- I don't quite know what to call that





# APC BACKUPS 600

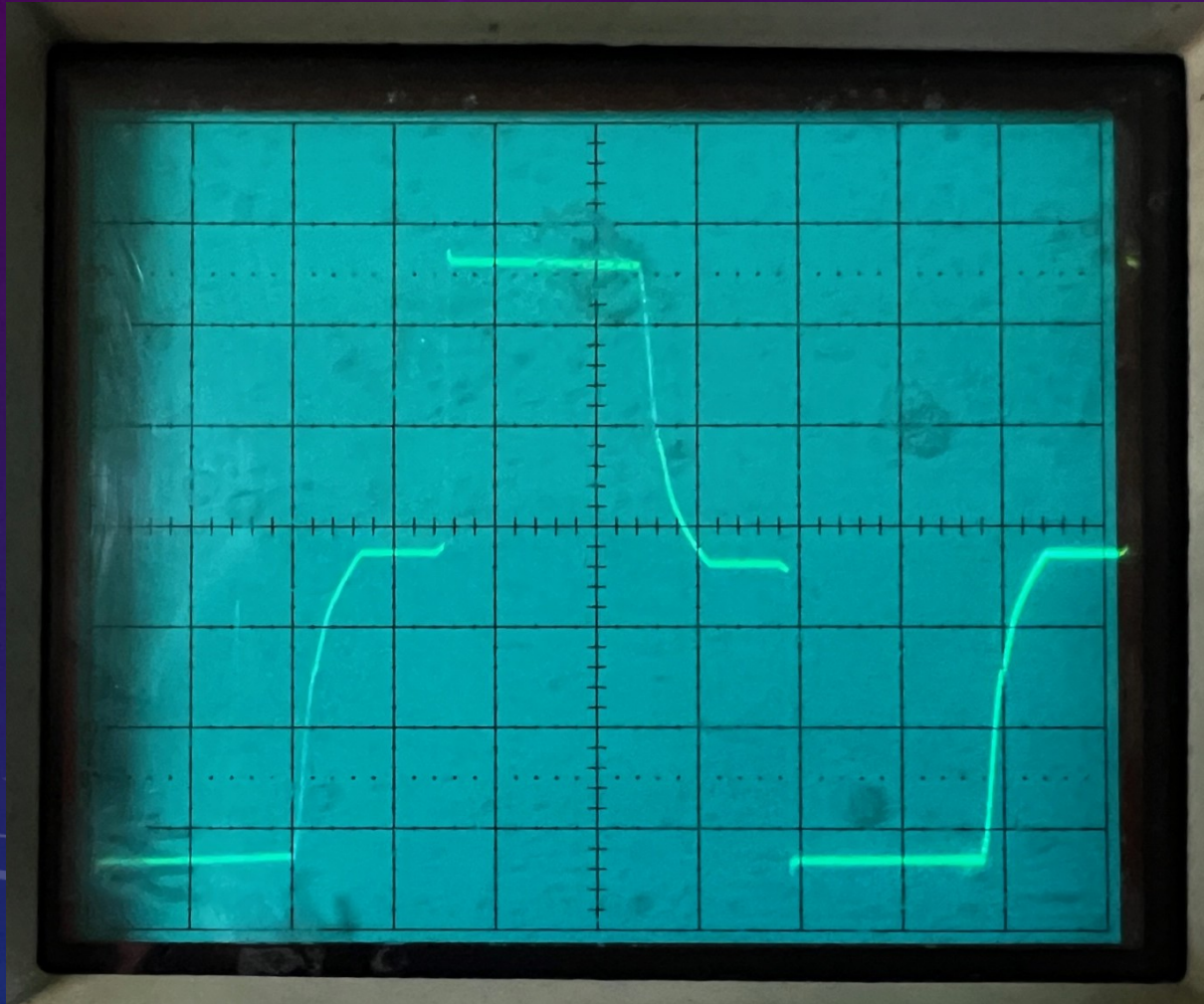


- Overshoot on leading edge





# APC BACKUPS NS 1350

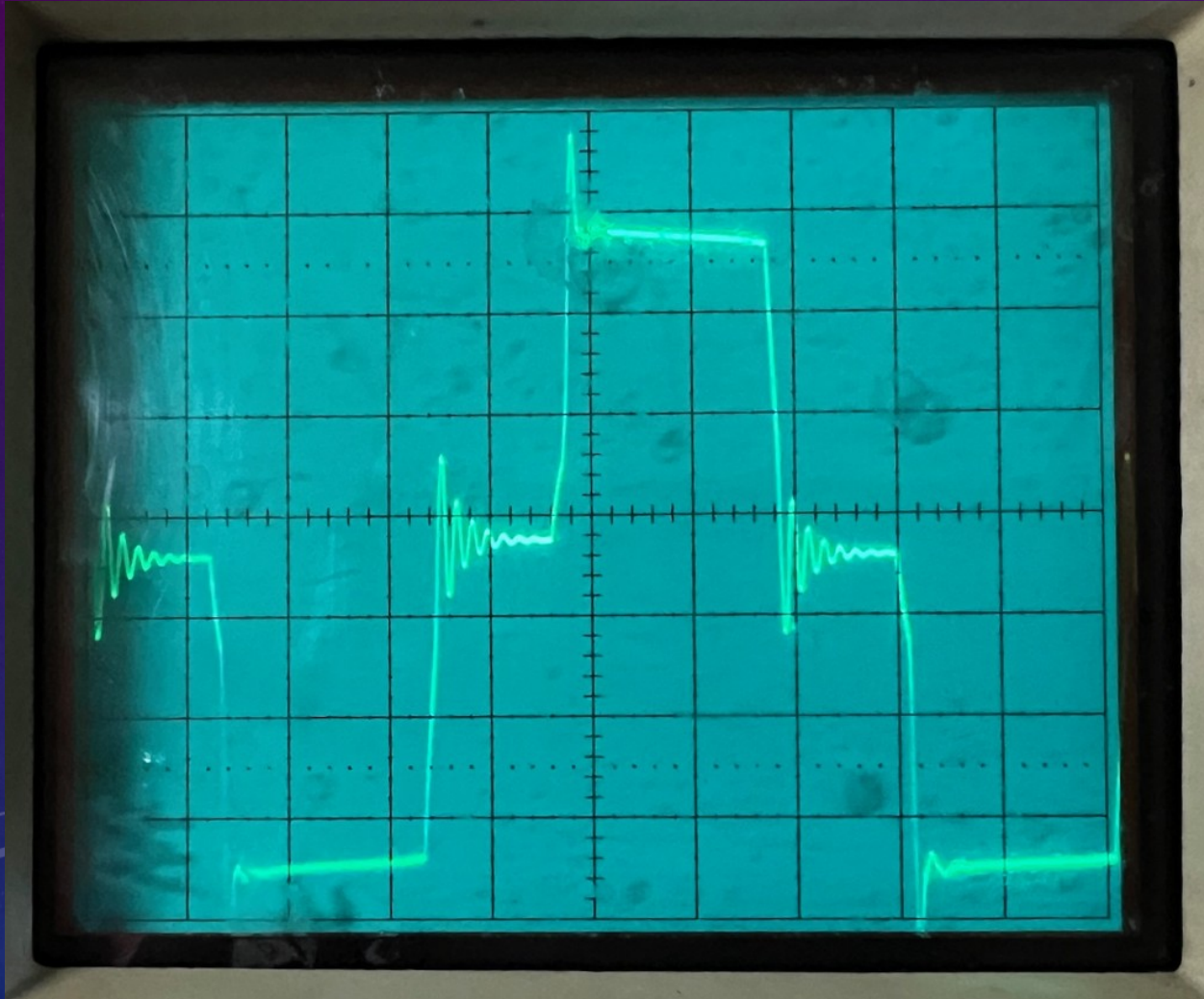


- Decay on trailing edge





# TRIPP LITE SMART1500 LCDT



- Pick a voltage,  
any voltage  
around 110V would be nice





# CONCLUSIONS

- You get what you pay for
  - The nice sine wave UPS units are in the \$500-\$1500 and up range
- The cheap units generate bad power, but also do not tolerate bad power

