Lab 11: Relaxation oscillators
Empty bucket
Slow descent
Cycle repeats
Relaxation oscillators:

Cycle of adding and dissipating energy

Asymmetric, non-sinusoidal time behavior

Examples:
- Laser physics
- Heart muscle
- Vocal cords
- Predator-prey population cycles

B. van der Pol
(1889-1959)
Storing and releasing energy with a capacitor

Determine charging rate
Don't use impedance $Z = 1/j\omega C$
Storing and releasing energy with a capacitor

\[ V_{\text{cap}} = V_B \left( 1 - e^{-t/RC} \right) = V_B \left( 1 - e^{-t/\tau} \right) \]
Storing and releasing energy with a capacitor

V_B

R

C

Charging

Neon lamp

V_{cap}

V_B

V_{cap}

t
Storing and releasing energy with a capacitor

\[ V_{\text{cap}} \]  

Discharge

\[ V_{\text{B}} \]

Neon lamp

\[ V_{\text{B}} \]  

\[ t \]
Neon Lamp Relaxation Oscillator

Waveform Chart

Capacitor Voltage

Time

R

C

Charging

DC voltage: 74.5
Time constant (sec): 1
\( dt = 0.2 \)
Storing and releasing energy with a capacitor: Capacitive discharge ignition

- 12 V
- Electronic switch
- R
- C
- Coil (Step-up transformer)
- 20 kV
- Crankshaft position sensor
Relaxation oscillator: Implementation with Op-Amp

- Inverting Input ($V^-$)
- Non-inverting Input ($V^+$)

Op-Amp without feedback: Infinite gain (Open loop gain of ideal Op-Amp)
Relaxation oscillator: Implementation with Op-Amp

V− greater than V+
Output drives to negative ∞
Clamped at −15V of power supply
Relaxation oscillator:
Implementation with Op-Amp

V+ greater than V−

Output drives to positive ∞
Clamped at +15V of power supply
Relaxation oscillator:
Implementation with Op-Amp

Make $V+$ a reference voltage

Voltage divider: $R1 = R2$

$V+ = \frac{1}{2} V_{\text{OUT}} = +7.5V$ or $-7.5V$
Relaxation oscillator:
Implementation with Op-Amp

Add RC feedback to inverting input

V− can't follow $V_{OUT}$ instantly

Capacitor charges with $\tau = R3C$
Relaxation oscillator: Implementation with Op-Amp

Add RC feedback to inverting input

$V^-$ can't follow $V_{OUT}$ instantly

Capacitor charges with $\tau = R3C$

$\frac{1}{2} V_{OUT}$
Relaxation oscillator: Implementation with Op-Amp

Add RC feedback to inverting input

$V_-$ can't follow $V_{OUT}$ instantly

Capacitor charges with $\tau = R3C$

Graph showing $V_{OUT}$ over time with $+15V$, $-15V$, and $\frac{1}{2} V_{OUT}$ crossings.
Relaxation oscillator: Implementation with Op-Amp

If $R_1 = R_2$

Period: $2(\ln 3)R_3C$
**Slewing:** Op-Amp cannot switch instantly

Limits the maximum oscillator frequency

- **Ideal**
- **Slewing visible**
- **Slewing severe**
555 Timer Chip

Make rectangular wave relaxation oscillator

Period adjustable with R and C

Set from microseconds to hours

Adjustable duty cycle: $T_{ON} / \text{Period}$

- 50% duty cycle
- 33% duty cycle
- 12.5% duty cycle
VI Server Architecture

- Programatically control Front Panel objects  
  [These objects are in the Control Class]

- Programatically edit properties of a running VI  
  [These objects are in the VI Class]

Objects have **PROPERTIES** and **METHODS**

**PROPERTIES** are attributes of an object (eg. color, size, visibility, etc)  
**METHODS** are actions or operations of an object (eg. initializing a control)

**PROPERTIES** are changed programatically with **PROPERTY NODES**  
**METHODS** are changed programatically with **INVOKE NODES**