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

Cycle of adding and dissipating energy

Asymmetric, non-sinusoidal time behavior

Examples of systems with this behavior:
- Laser physics
- Heart muscle
- Vocal cords
- Predator-prey population cycles

Feedback Mechanism

- Energy Storage Device
  (capacitor, material system, gain medium for lasers, ...)
- Rapid Switching device that releases the stored energy
  (diode, switch, discharge lamp, opamp, etc...)

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

Determine charging rate
Don't use impedance $Z = 1/j\omega C$

$$C = \frac{Q_{CAP}}{V_{CAP}}$$
Storing and releasing energy with a capacitor

\[ V_{\text{cap}} = V_B \left( 1 - e^{-t/RC} \right) = V_B \left( 1 - e^{-t/\tau} \right) \]

\[ C = \frac{Q_{\text{CAP}}}{V_{\text{CAP}}} \]
Storing and releasing energy with a capacitor

![Diagram showing a circuit with a resistor (R), a capacitor (C), and a neon lamp. The capacitor is being charged, and the voltage across it (V_{cap}) is increasing over time (t), approaching VB.}]
Storing and releasing energy with a capacitor

Discharge

Vcap

VB

Vcap

VB

t
Laser Oscillators: Optical gain inside a feedback cavity

- Optical pumping
- Excitation & Amplification
- Feedback
  \( \rightarrow \) Oscillation

\[ I(\nu) \]
Laser Oscillators:
Optical gain inside a feedback cavity

Optical pumping

Q-switch
Control amount of feedback
Allows for build up of stored energy in Gain medium
When switch is “opened”, the stored energy is released

Gain medium stores energy: analogous to Capacitor
Relaxation oscillator: Implementation with Op-Amp

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

Positive voltage

\[ V_- \text{ greater than } V_+ \]
Output drives to negative \(\infty\)
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: $R_1 = R_2$

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

Add RC feedback to inverting input

V– can't follow VOUT instantly

Capacitor charges with $\tau = R_3C$

\[ \frac{1}{2} \text{VOUT} \]
Relaxation oscillator:
Implementation with Op-Amp

Add RC feedback to inverting input

V− can't follow VOUT instantly

Capacitor charges with \( \tau = R_3C \)
Relaxation oscillator: Implementation with Op-Amp

Add RC feedback to inverting input

V– can't follow VOUT instantly

Capacitor charges with \( \tau = R_3 C \)
Relaxation oscillator:
Implementation with Op-Amp

If $R_1 = R_2$

Period: $2\ln(3)R_3C$

$$V_{\text{OUT}}$$
Slewing: Op-Amp cannot switch instantly

Limits the maximum oscillator frequency
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

More tools...

How to....?

– Control objects in the Front Panel
  Objects: Plots, Charts, Controls, indicators, etc…

– Edit properties of a running VI

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

**PROPERTIES** are attributes of an object
• Color
• Size
• Position

**METHODS** are actions or operations of an object
• Initializing a control
• Save data to a spread sheet
• Sending data via Ethernet

**PROPERTIES** are changed with **PROPERTY NODES**

**METHODS** are changed with **INVOKE NODES**

More advanced, data processing, communication.. (left for later)
Storing and releasing energy with a capacitor: Capacitive discharge ignition