

SNS COLLEGE OF TECHNOLOGY



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COIMBATORE-641 035, TAMIL NADU

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Course Name: 23ECT203 LINEAR INTEGRATED CIRCUITS

II YEAR/VI SEMESTER

UNIT II –APPLICATIONS OF OPERATIONAL AMPLIFIERS

Topic :Low-pass, high-pass and band-pass Butterworth filters



- ✓ Maximally flat frequency response in passband
- ✓ Monotonically decreasing gain in stopband
- ✓ No ripple in passband or stopband
- ✓ Widely used in audio and signal processing

Key Feature

Optimal for applications requiring flat passband response

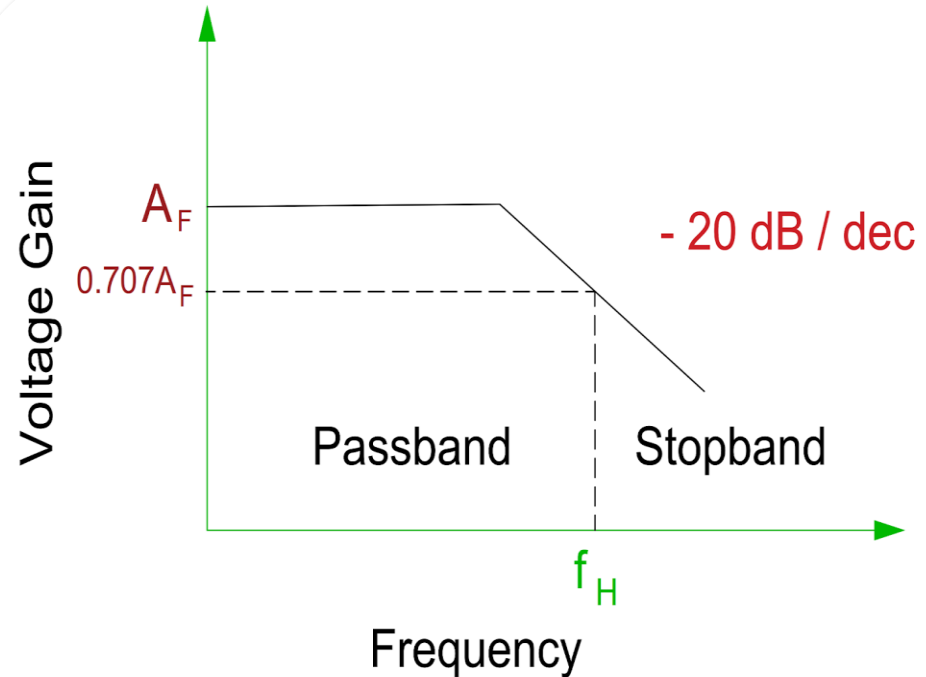
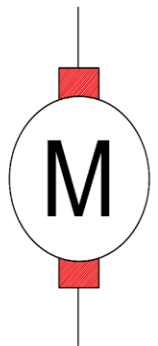
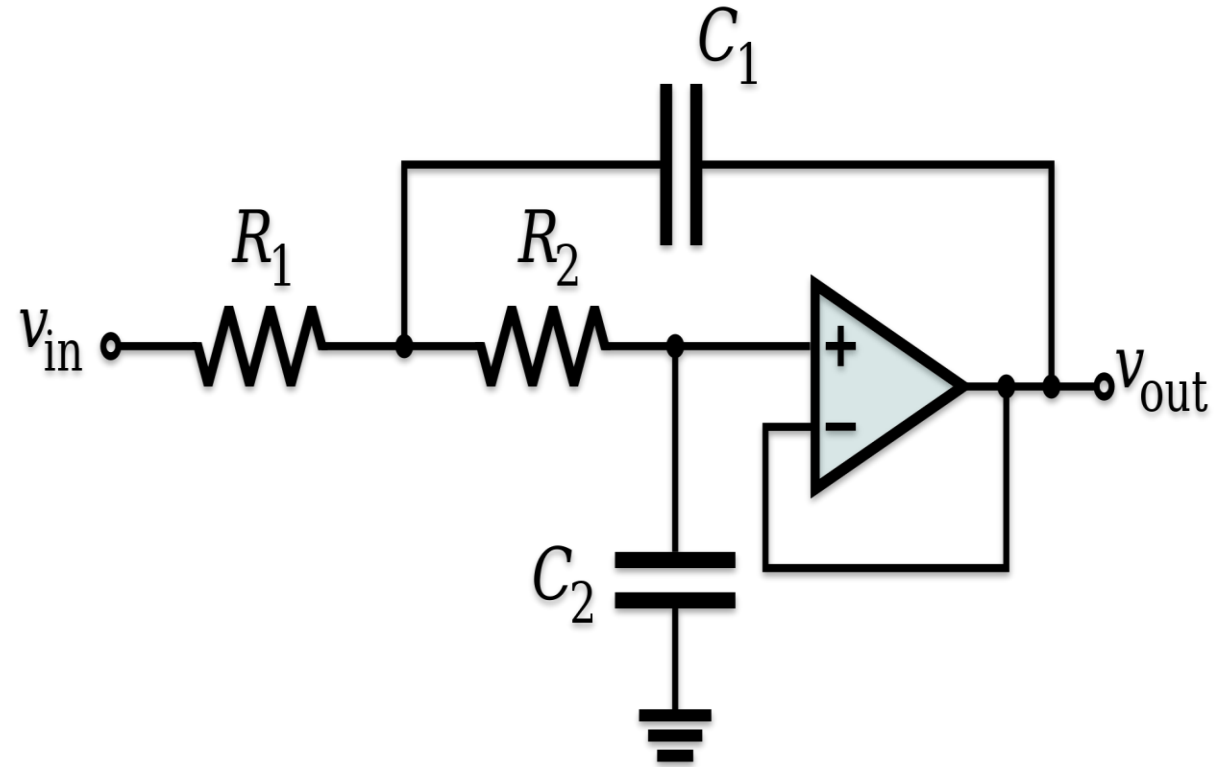


FIG : Frequency Response First order Low Pass Butterworth Filter



- ✓ Passes frequencies below cutoff frequency f_c
- ✓ Attenuates frequencies above f_c
- ✓ Flat response in passband
- ✓ **Cutoff Frequency**
-3dB point (half-power point)



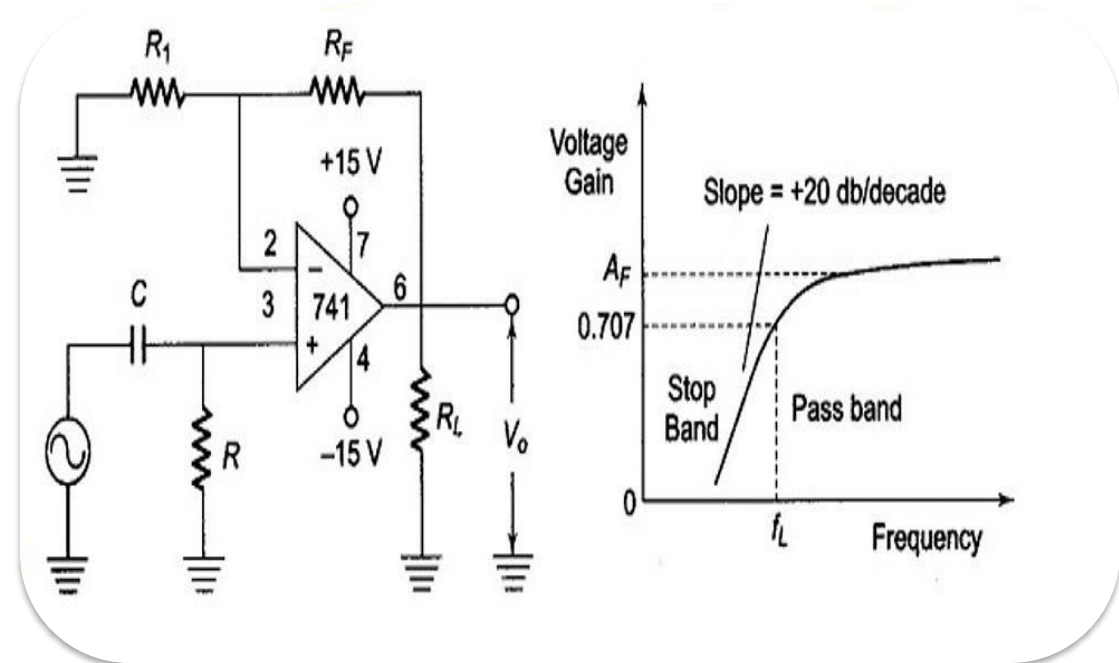
Transfer Function

$$H(s) = K / [1 + (s/\omega_c)^n]$$

- ✓ Passes frequencies above cutoff frequency f_c
- ✓ Attenuates frequencies below f_c
- ✓ Flat response in passband
- ✓ **Cutoff Frequency**
-3dB point (half-power point)

Transfer Function

$$H(s) = K(s/\omega_c)^n / [1 + (s/\omega_c)^n]$$



✓ Passes frequencies between f_L and f_U

✓ Attenuates frequencies outside band

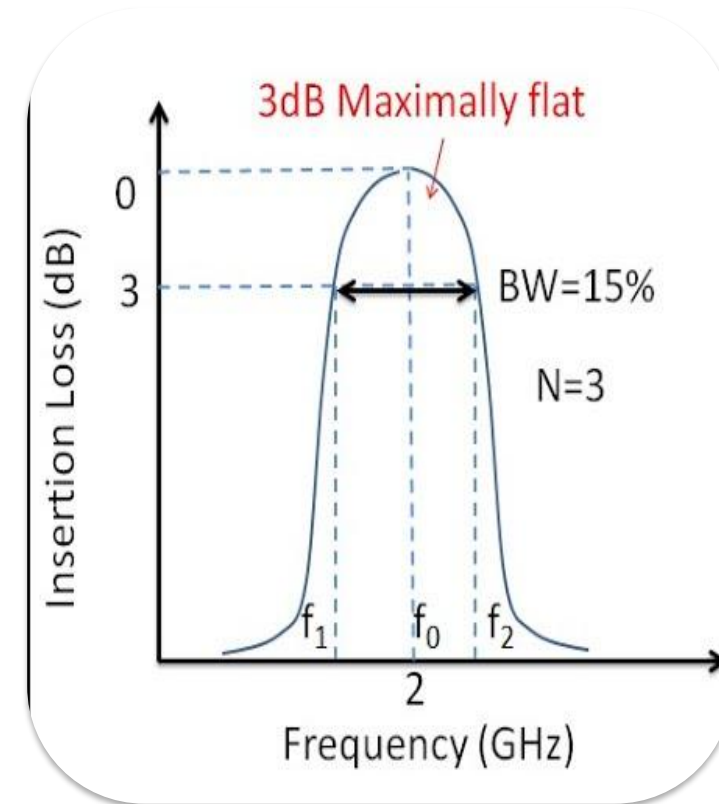
✓ Flat response in passband

✓ Bandwidth

$$BW = f_U - f_L$$

Key Features

$$\text{Center frequency: } f_0 = \sqrt{f_L \times f_U}$$





- ✓ Maximally flat magnitude response in passband
- ✓ No ripple in passband or stopband
- ✓ Monotonically decreasing in stopband

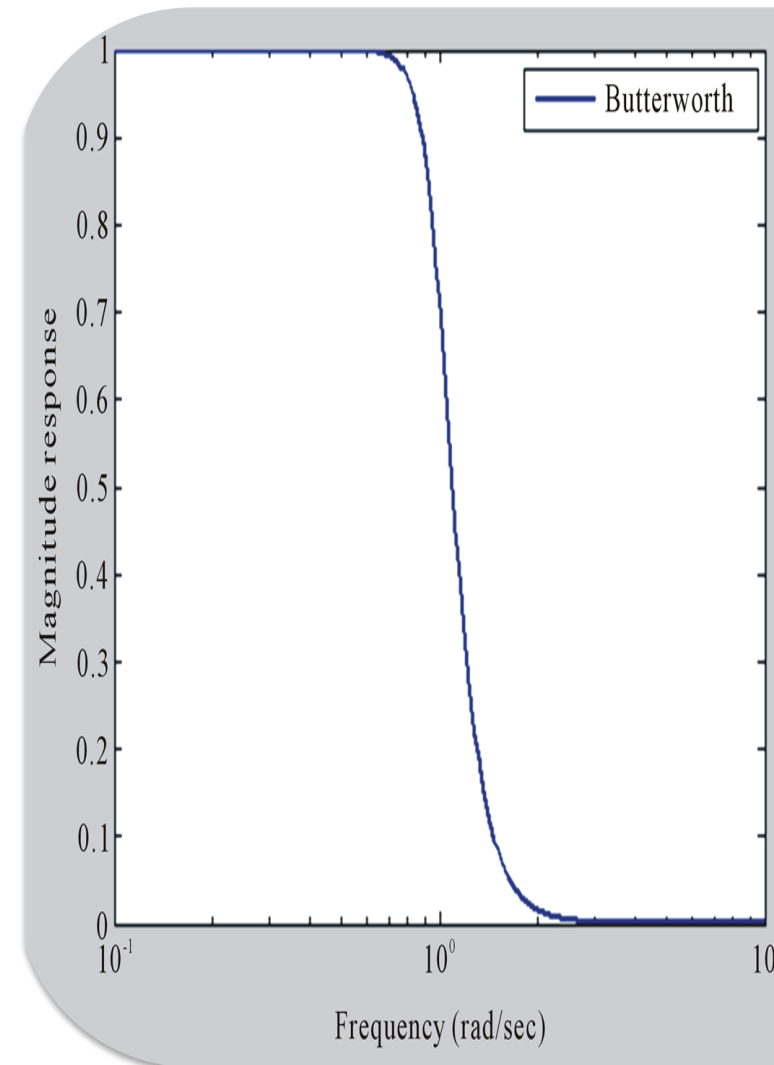
✓ Rolloff Rate

20n dB/decade

n = filter order

Transfer Function

$$|H(j\omega)| = 1 / \sqrt{1 + (\omega/\omega_c)^{2n}}$$



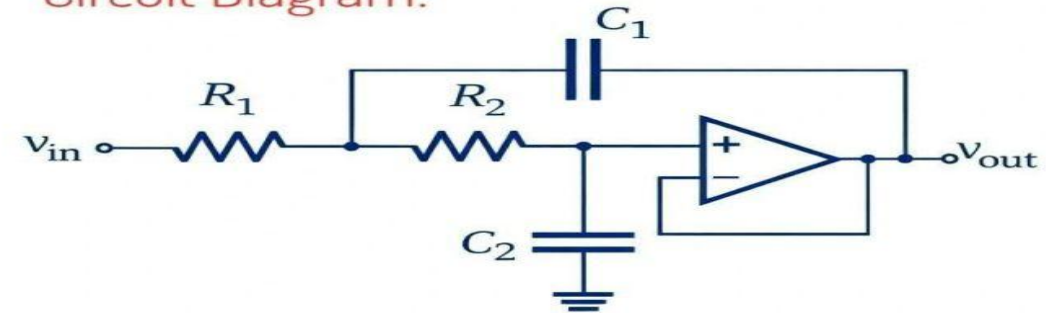


- ✓ Uses operational amplifier
- ✓ Sallen-Key topology
- ✓ Provides gain and filtering
- ✓ Suitable for Butterworth design

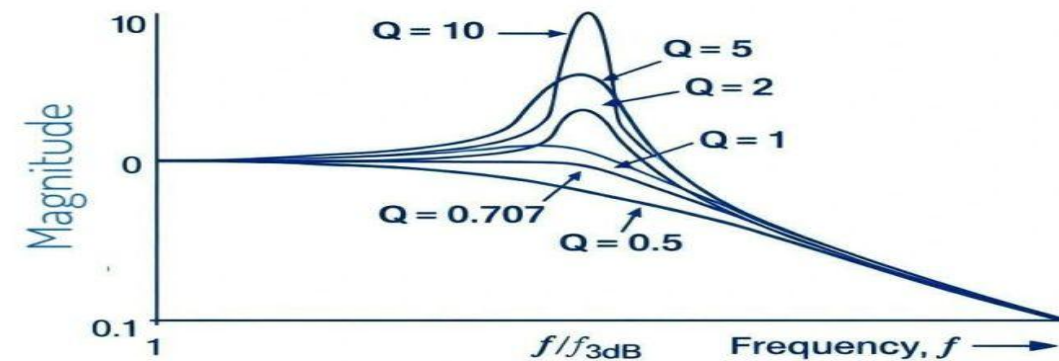
Key Features

Second-order active filter with feedback

Circuit Diagram:



Frequency Response :



↘ Low-pass

- ✓ Passes low frequencies
- ✓ Attenuates high frequencies
- ↘ Cutoff: f_c

↗ High-pass

- ✓ Passes high frequencies
- ✓ Attenuates low frequencies
- ↘ Cutoff: f_c

·|·|· Band-pass

- ✓ Passes frequency band
- ✓ Attenuates outside band
- ↘ $BW = f_U - f_L$

Audio Processing

- Audio equalizers
- Speaker crossovers
- Noise reduction

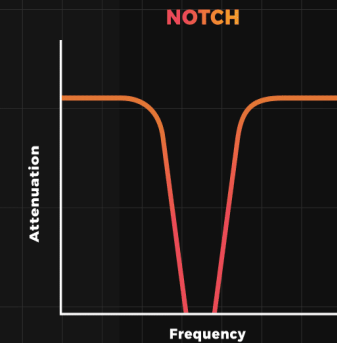
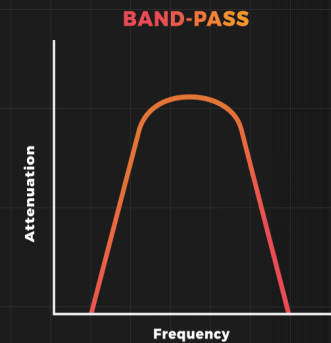
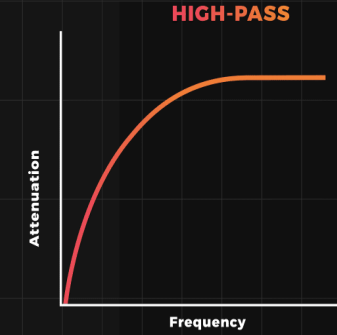
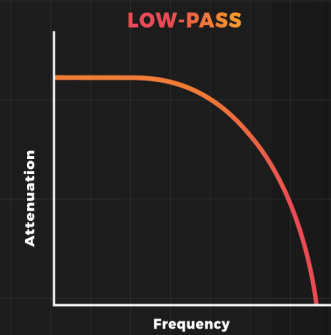
Signal Conditioning

- Anti-aliasing filters
- Smoothing circuits
- Data acquisition

Communications

- Channel selection
- Modulation/demodulation

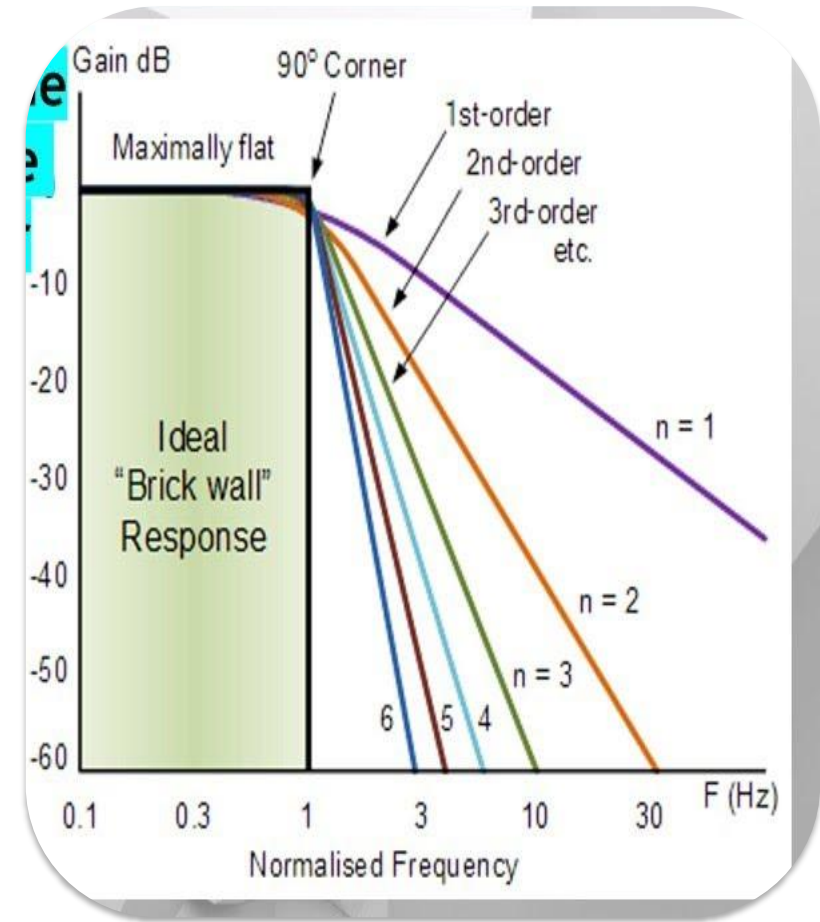
AUDIO FILTER TYPES





Stage 1: Empathize

- Understanding student challenges in filter design
- Identifying frequency response concepts
- Recognizing practical implementation issues
- Analyzing common mistakes in filter applications



Focus

Understanding real-world filter design challenges

Establishing clear learning objectives for filters

 Defining key concepts: cutoff frequency, bandwidth, rolloff

 Setting measurable goals

 Identifying assessment criteria

Objective

Master Butterworth filter design principles



Stage 3: Ideate



Brainstorming filter configurations



Analyzing active vs passive filter designs



Exploring component combinations







Developing systematic analysis approaches

Focus

Creative filter design solutions

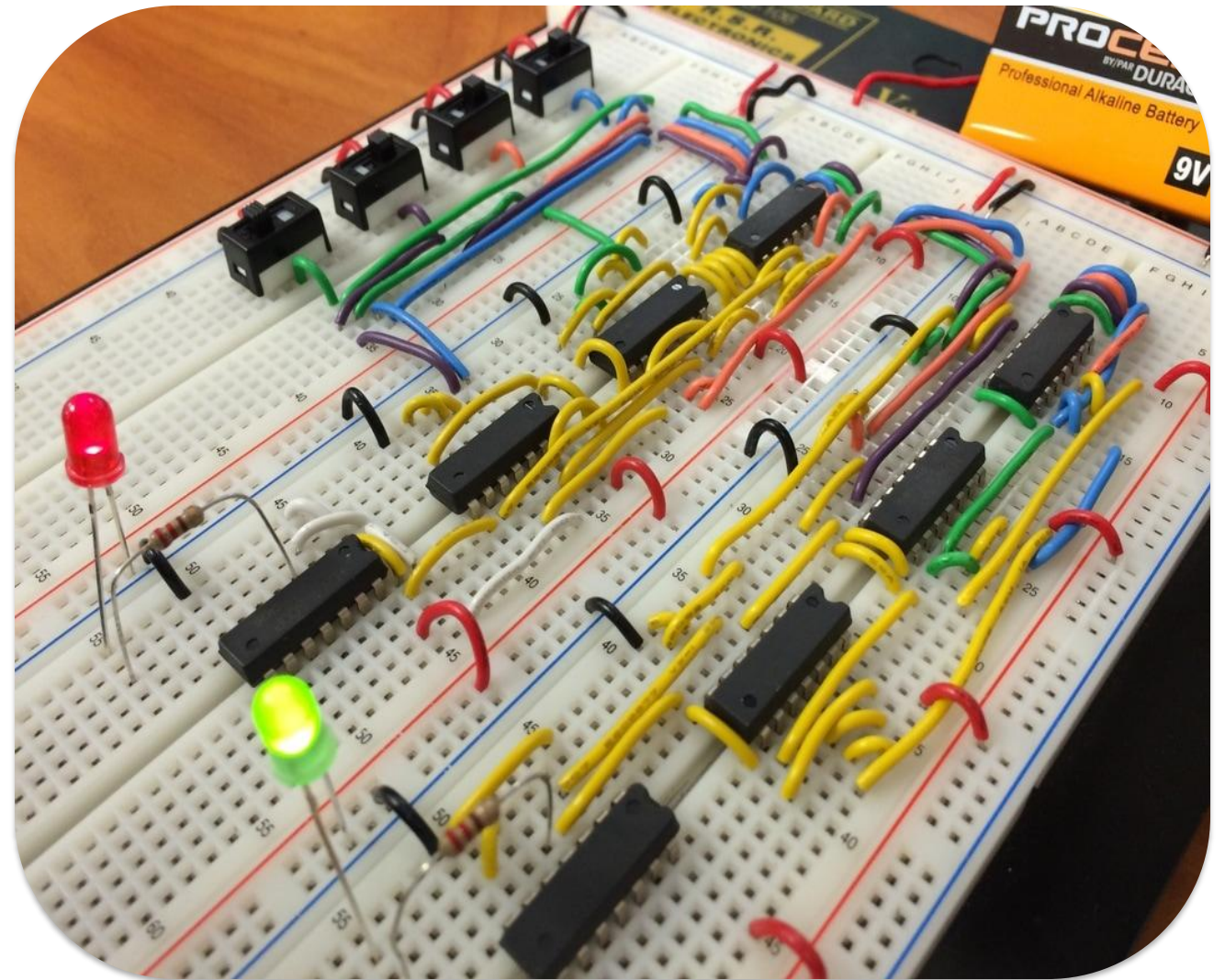


Stage 4: Prototype

-  Building low-pass filter prototype
-  Building high-pass filter prototype
-  Building band-pass filter prototype
-  Testing component values

Focus

Hands-on filter circuit implementation



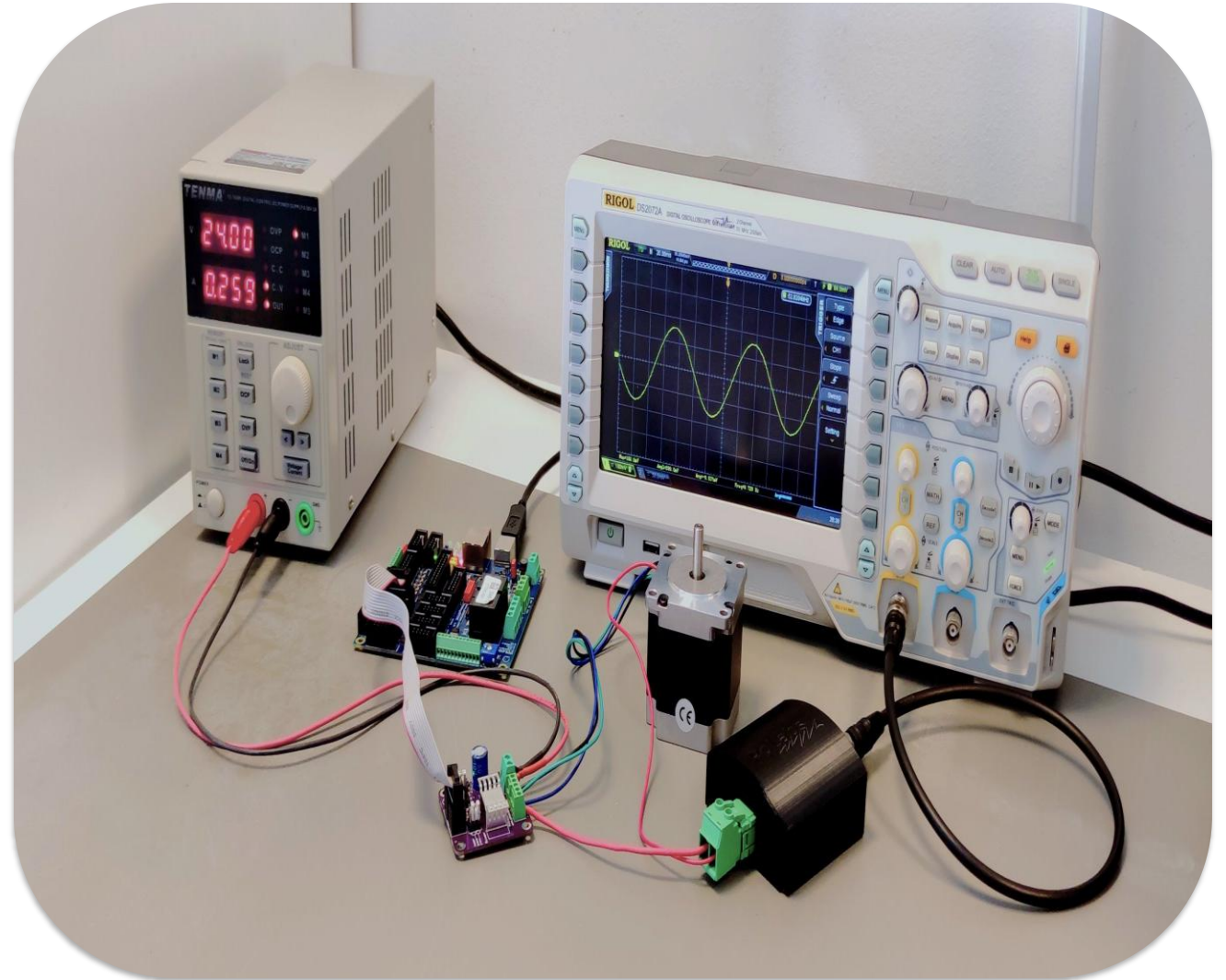


Stage 5: Test

- ✓ Measuring frequency response with oscilloscope
- ⚡ Verifying cutoff frequencies
- 📊 Checking filter performance
- ⚙️ Validating Butterworth characteristics

Focus

Performance validation and measurement





Q1:
Explain Butterworth filter characteristics

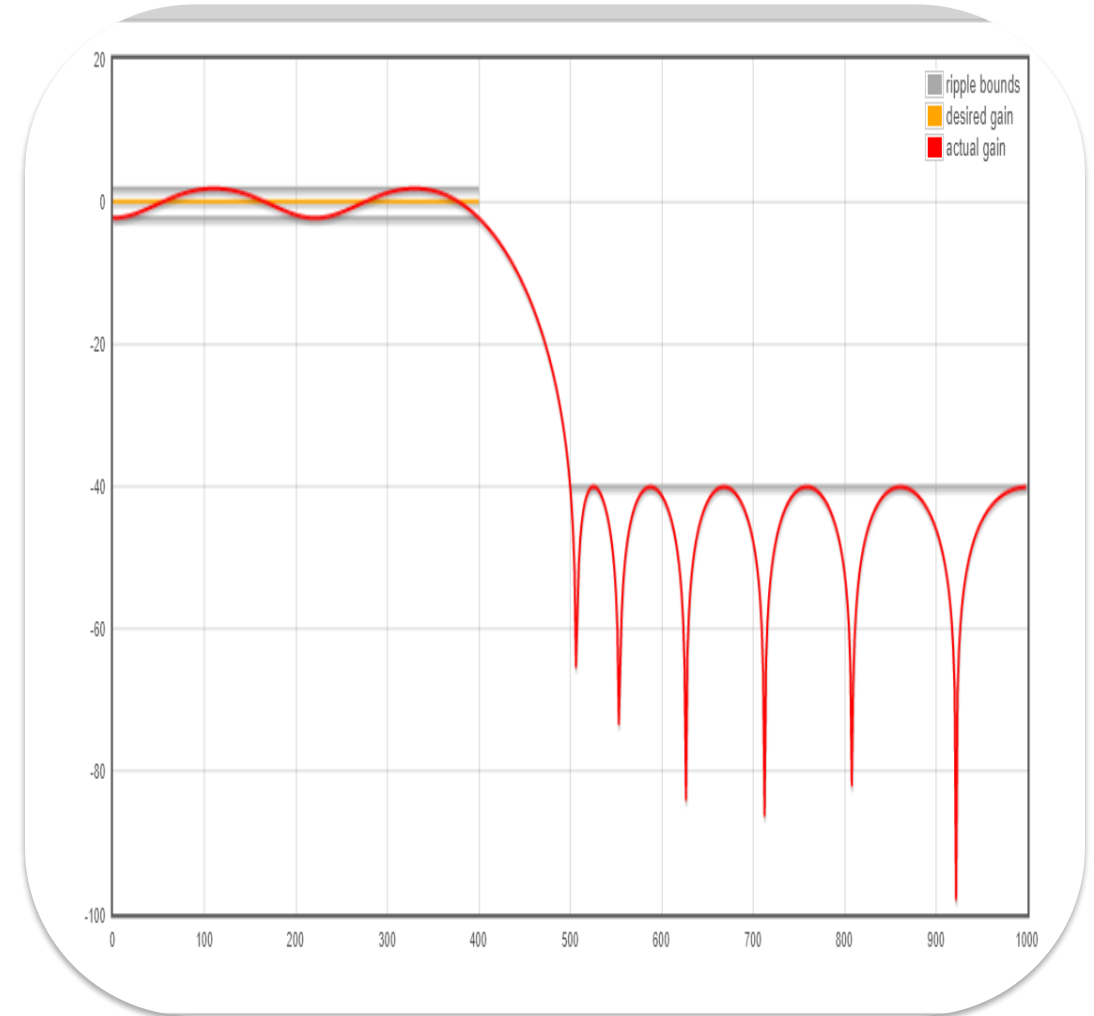
Q2:
Derive cutoff frequency formula

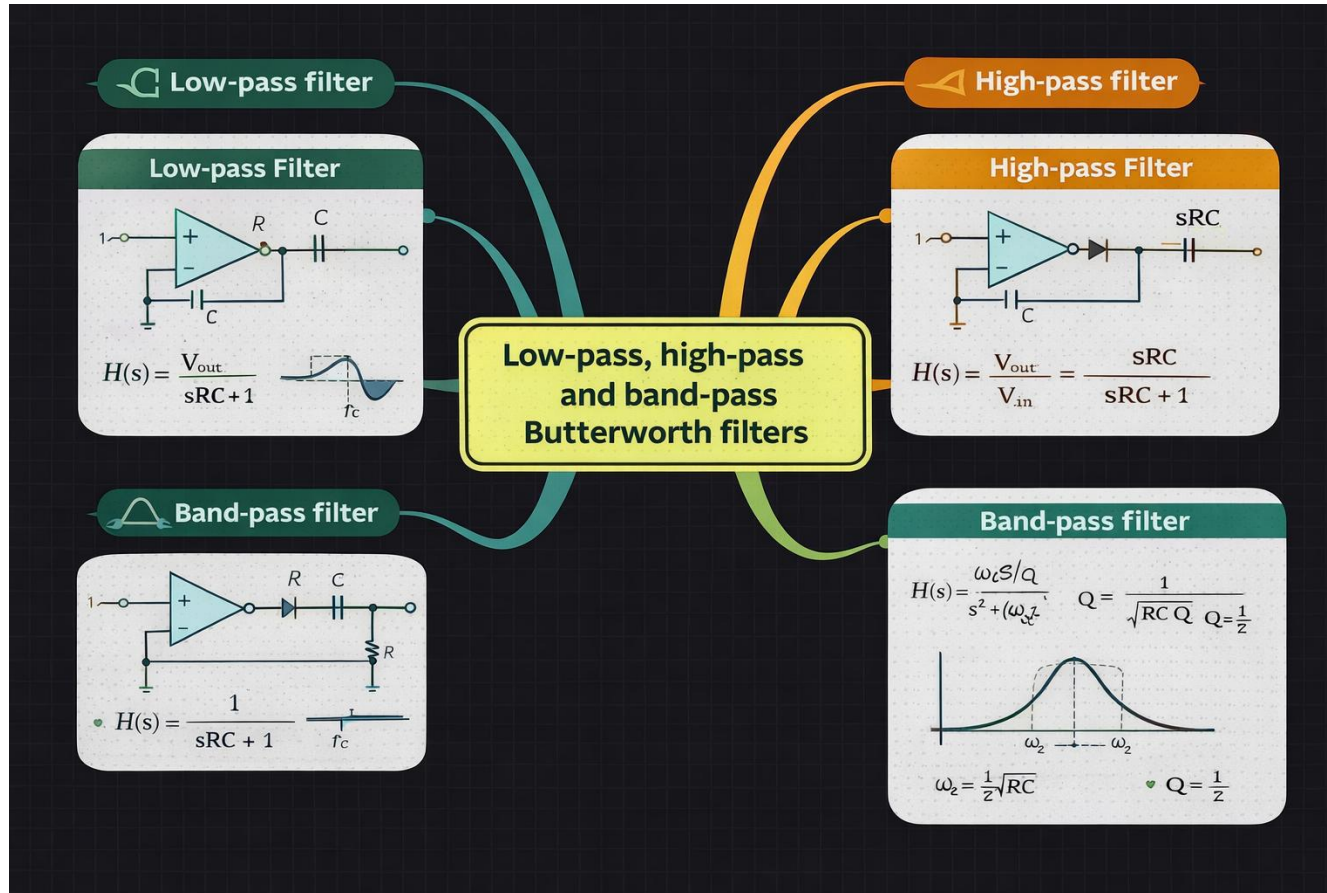
Q3:
Compare LPF, HPF and BPF

Q4:
Calculate filter order

Key Concepts

- Flat passband
- Cutoff frequency
- Rolloff rate
- Bandwidth







Textbooks

- Sergio Franco - "Design with Operational Amplifiers and Analog Integrated Circuits"
- D. Roy Choudhry & Shail Jain - "Linear Integrated Circuits"
- Ramakant A. Gayakwad - "OP-AMP and Linear ICs"



Online Resources

- Texas Instruments Filter Design Handbook
- Analog Devices Design Guides
- Electronics Tutorials



- ✓ Butterworth filters have maximally flat passband
- ✓ No ripple in frequency response
- ✓ Three types: low-pass, high-pass, band-pass
- ✓ Widely used in audio and signal processing

Key Takeaway

Butterworth filters provide optimal performance for applications requiring flat passband response