BASICS OF BIOMEDICAL INSTRUMENTATION

UNIT III SIGNAL CONDITIONING CIRCUITs

III UNIT

- Need for bio-amplifier - differential bio-amplifier, Impedance matching circuit, isolation amplifiers, Power line interference, Right leg driven ECG amplifier, Band pass filtering

Need for bio-amplifier

- **biological**/bioelectric signals have low amplitude and low frequency. Therefore, to increase the amplitude level of biosignals **amplifiers** are designed. The outputs from these **amplifiers** are used for further analysis and they appear as ECG, EMG, or any bioelectric waveforms

Need for bio-amplifier

A **Bioamplifier** is an electrophysiological device, a variation of the instrumentation amplifier, used to gather and increase the signal integrity of physiologic electrical activity for output to various sources. It may be an independent unit, or integrated into the electrodes.

PREAMPLIFIER

The **purpose of a preamp** is to amplify low level signals to line level, i.e. the “standard” operating level of your recording gear. Microphone signals are usually way below the nominal operating level, so a lot of gain is required, usually around 30-60 dB, sometimes even more.

types of preamplifiers

- Three basic **types of preamplifiers** are available: the current-sensitive **preamplifier**, the parasitic-capacitance **preamplifier**, and the charge-sensitive **preamplifier**.

purpose of a preamp

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Differential bio-amplifier,

- A **differential amplifier** is a type of electronic **amplifier** that amplifies the difference between two input voltages but suppresses any voltage common to the two inputs.

advantages

- Differential amplifiers offer many advantages for manipulating differential signals. They provide immunity to external noise; a 6-dB increase in dynamic range, which is a clear advantage for **low**-voltage systems; and reduced second-order harmonics

disadvantage

- The main advantages of **Differential Amplifier**, it can eliminate noise present in the input signal, and linear in nature. The main **disadvantage** of the **Differential Amplifier** is, it rejects the common mode signal when operating.

Applications

- Applications of Differential Amplifiers. Generally, we use differential amplifier that acts as a **volume** control circuit. The differential operational amplifier can be used as an automatic gain control circuit. Some of the differential operational amplifier can be used for Amplitude modulation.

Operational amplifier symbol The inverting and non-inverting inputs are distinguished by "−" and "+" symbols (respectively) placed in the amplifier triangle. V_{s+} and V_{s-} are the power supply voltages; they are often omitted from the diagram for simplicity but must be present in the actual circuit.

What is a Differential Amplifier?

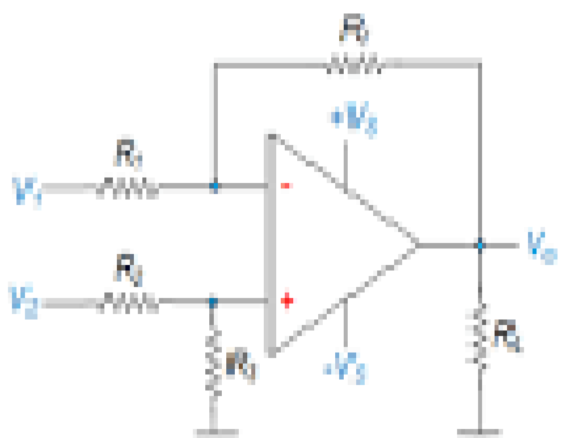

Figure 2 Differential Amplifier Using an Op-Amp

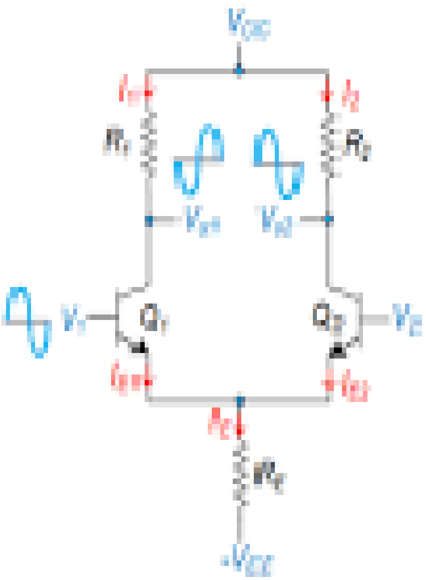

Figure 1 A BJT Differential Amplifier

Electrical 4 U

III UNIT

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INSTRUMENTATION AMPLIFIER

- An **instrumentation** (or instrumentational) **amplifier** (sometimes shorthanded as In-**Amp** or InAmp) is a type of differential **amplifier** that has been outfitted with input buffer **amplifiers**, which eliminate the need for input impedance matching and thus make the **amplifier** particularly suitable for use in measurement and test

INSTRUMENTATION AMPLIFIER

The ratio of internal resistors, R2/R1, sets the **gain** of the internal difference **amplifier**, which is typically G = 1 V/V for most **instrumentation amplifiers** (the overall **gain** is driven by the **amplifier** in the first stage). The balanced signal paths from the input to the output yield excellent CMRR

Features

- Instrumentation amplifiers are **precision**, integrated operational amplifiers that have differential input and single-ended or differential output. Some of their key features include very high common mode rejection ratio (CMRR), high open loop gain, low DC offset, low drift, low **input impedance**, and low noise.

Differential amplifiers vs Instrumentation amplifiers

- **Differential amplifiers** are specifically designed to amplify the **difference between** 2 input signals. ... **Instrumentation amplifiers** are specifically designed for applications that require excellent DC characteristics, high input impedance, low noise and drift.

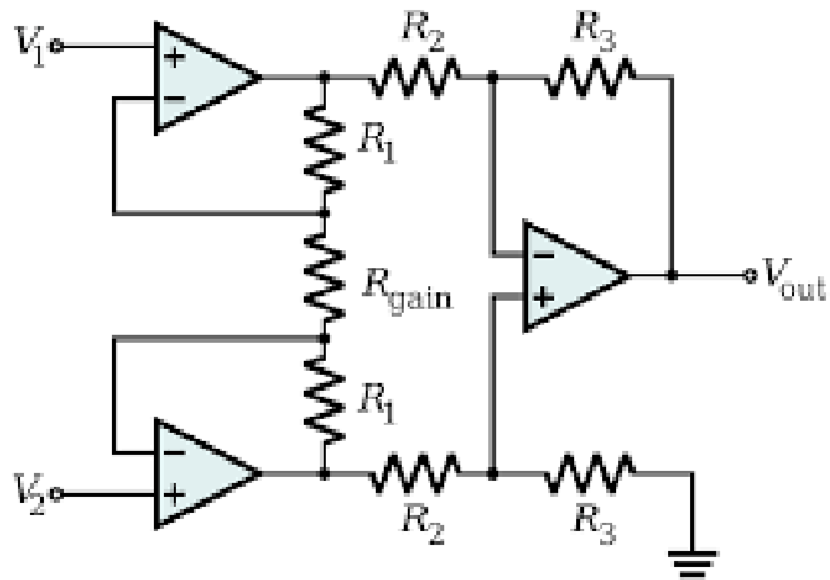
Advantage

- Offset voltage is minimized. Voltage Gain is high as the configuration uses high precision resistors. The Gain of the circuit can be varied by using specific value of resistor. **Non**-linearity is very low.

Disadvantages

- **Instrumentation amplifiers** are used where great accuracy andstability of the circuit both short and long-term are required. **Disadvantages** of **instrumentation amplifier**. For transmission purpose for long range, noise also gets superimposed along the original wave.

Circuit Diagram



- An instrumentation amplifier is a type of differential amplifier that has been outfitted with input buffer amplifiers, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment.

Impedance matching circuit

- he term “**impedance matching**” is rather straightforward. It's simply **defined** as the process of making one **impedance** look like another. Frequently, it becomes necessary to **match** a load **impedance** to the source or internal **impedance** of a driving source

- The T-match impedance matching circuit is one of the circuits used to match the impedance between two points, usually a source and a load. The circuit got its name because the **inductor** and the capacitor form a T-shape as shown in the schematic diagram below.

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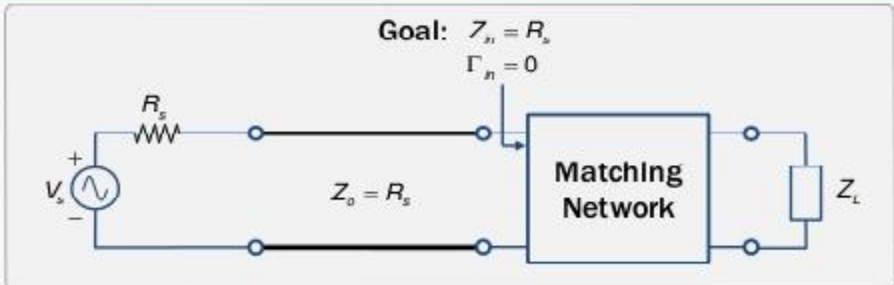
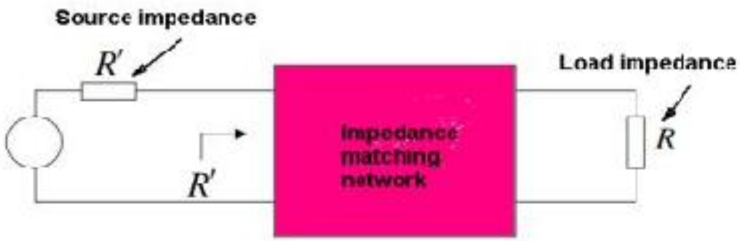
Impedance Matching



- The matching network is ideally lossless, to avoid unnecessary loss of power, and is usually designed so that the impedance seen looking into the matching network is Z_o (matched with the transmission line) or R_s (matched with the source impedance when no line connected).
- Maximum power is delivered when the load is matched to the line (assuming the generator is matched), and power los in the feed line is minimized.
- Impedance matching may be used to improve the signal-to-noise ratio or amplitude/phase errors in some applications.

Impedance matching



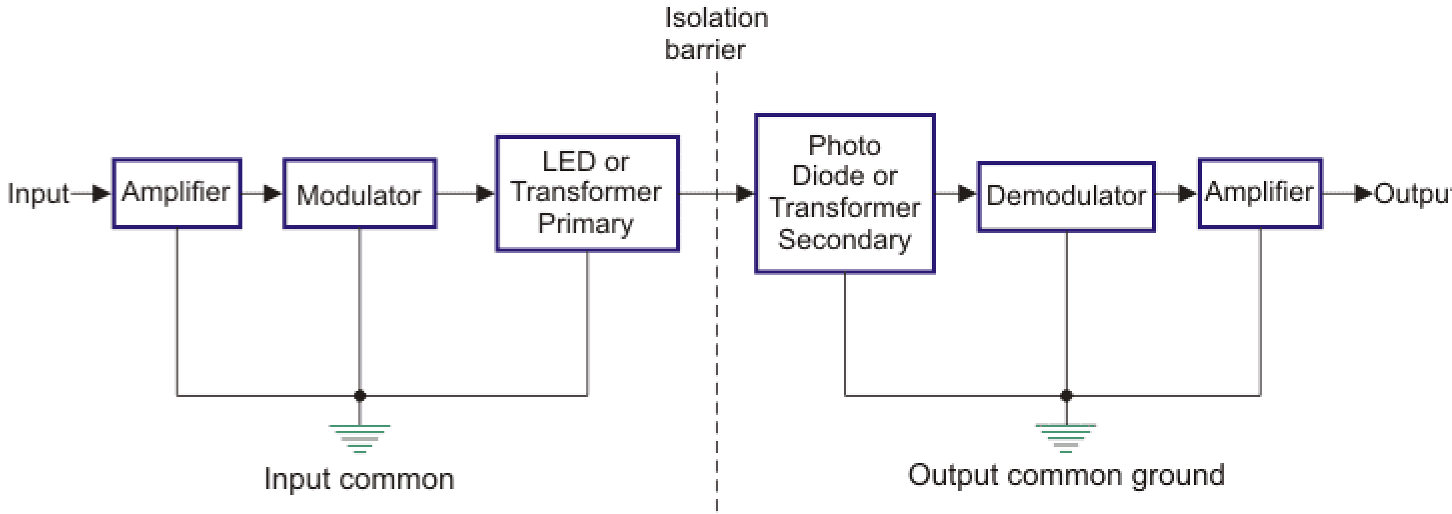
isolation amplifiers

- **Isolation** is the electrical or magnetic separation between two **circuits** and often used to separate two distinct sections of a power supply. The **isolation** provides a barrier across which dangerous voltages cannot pass in the event of a fault or component failure.

- An **isolation amplifier** (also called a unity-gain amplifier) is an op-amp circuit which provides isolation of one part of a circuit from another, so that power is not used, drawn, or wasted in a part of the circuit.

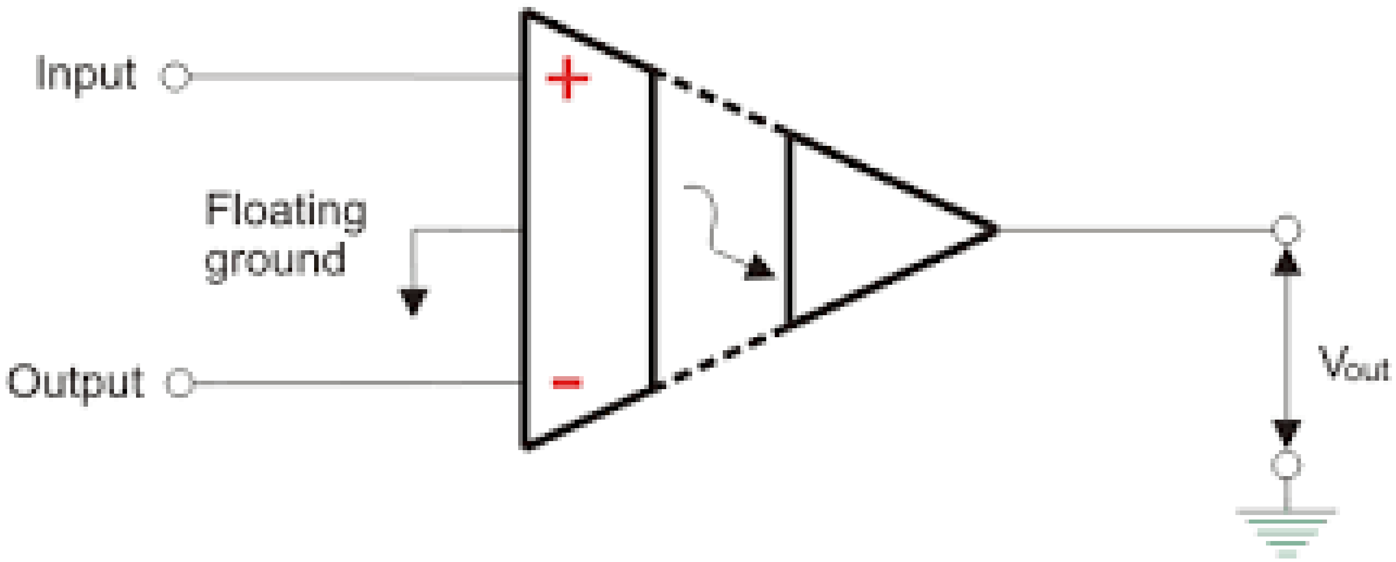
- The purpose of an isolation amplifier isn't to amplify the signal. The same signal that is input into the op amp gets passed out exactly the same. This means that output voltage is the same exact as the input voltage, meaning if 10V AC is input into a circuit, 10V AC is output.
- The purpose of an isolation amplifier is to isolate the circuit which appears before the amplifier from the circuit that appears after it.

BLOCK DIAGRAM



Block Diagram of Isolation Amplifier

SYMBOL



Symbol of Isolation Amplifier

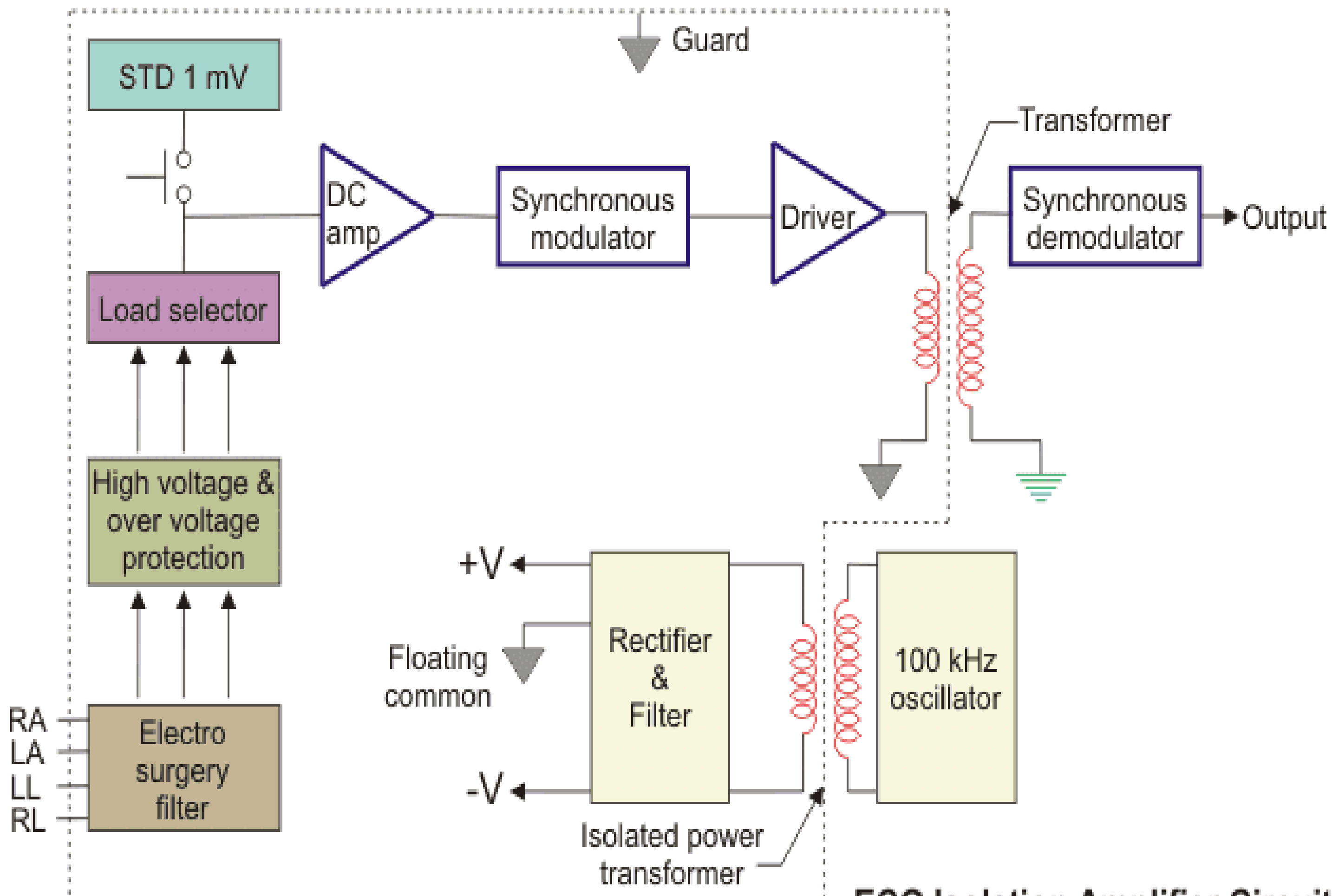
APPLICATION

- **Isolation** transformers provide separation from the power line ground connection to eliminate ground loops and inadvertent test equipment grounding. They also suppress high frequency noise riding on the power source.

ECG-isolation amplifiers

- BLOCK DIAGRAM

ECG-isolation amplifiers



ECG Isolation Amplifier Circuit

Power line interference

- The **powerline interference** (PLI), with the fundamental PLI component of 50 Hz/60 Hz and its harmonics, is one of the most disturbing **noise** sources in biopotential recordings that hampers the analysis of the electrical signals generated by the human body.

CAUSES

- **Power line interference** is easily recognizable since the interfering voltage in the ECG may have frequency 50 Hz. The **interference** may be due to stray effect of the alternating current fields due to loops in the patient's **cables**. Other **causes** are loos e contacts on the patient's **cable** as well as dirty electrodes

- The **powerline interference** (PLI), with the fundamental PLI component of 50 Hz/60 Hz and its harmonics, is one of the most disturbing noise sources in biopotential recordings that hampers the analysis of the electrical signals generated by the human body.

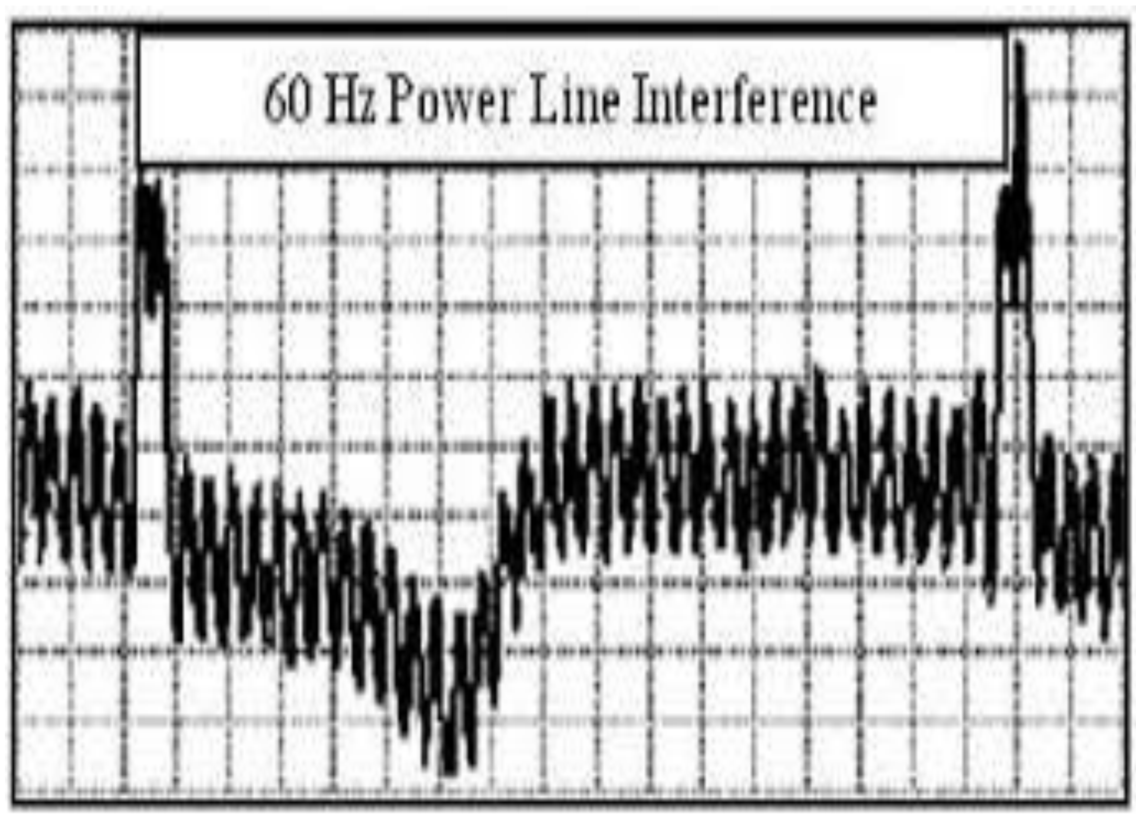
- The efficiency of notch filters and a subtraction procedure for power-line interference cancellation in electrocardiogram (ECG) signals is assessed. In contrast with the subtraction procedure, widely used digital notch filters unacceptably affect QRS complexes. The procedure eliminates interferences of variable amplitude and frequency. The frequency modulations are overcome by adaptive synchronized sampling. Initially, this is accomplished by current hardware power-line frequency measurement. Because this approach is impossible in battery-supplied and some computer-aided devices, a software measurement of the power-line interference period is developed.

- Modern electrocardiogram (ECG) amplifiers have extremely high common mode rejection ratio, for example, more than 80 dB. However, very often, the recordings are contaminated by residual interference, which represents common mode voltage converted to differential signal due to electrode impedance differences and parasitic currents through the patient body and the electrode cables.[1–3]

- The filters for interference suppression affect also the ECG frequency components in the neighborhood of the rated power-line frequency. Nevertheless, different types of digital notch filters are widely used.4,5 Narrow frequency band filters are vulnerable to larger power-line frequency deviations. Moreover, the transient time response is unacceptably long, for either adaptive or nonadaptive notch filters.4,6 Yoo *et al.*7 proposed a hardware notch filter, which varies its center frequency with the power-line frequency changes. However, the filter Q factor determines inadmissible wide rejection bandwidth in the signal spectrum

- A digital subtraction procedure for total interference cancellation was developed8 and improved upon, both for off-line and real-time implementation.9–19 It does not affect the ECG frequency components, even the ones coinciding with the power-line frequency.

POWERLINE INTERFERENCE



- Electrostatic and Electromagnetic coupling to AC signals

- Proper grounding(common impedance coupling)

Common-impedance coupling occurs when two or more circuits share a **common ground** and is the result of a shared **impedance** in a shared **ground** path

Signal Ground

- **Signal Ground** is a reference point from which that **signal** is measured, due to the inevitable voltage drops when current flows within a circuit, some '**ground**' points will be slightly different to others. There may be several **signal grounds** in a circuit

Techniques for cancellation of power line interference

- The main software **methods** for PLI cancelation are: (1) band stop digital filters; (2) fixed—frequency notch filters; (3) neural networks; (4) adaptive filters; (5) blind source separation; (6) Kalman filters; (7) time-frequency processing of nonstationary signals (wavelet transform); (8) subtraction **methods**;

Right leg driven ECG amplifier

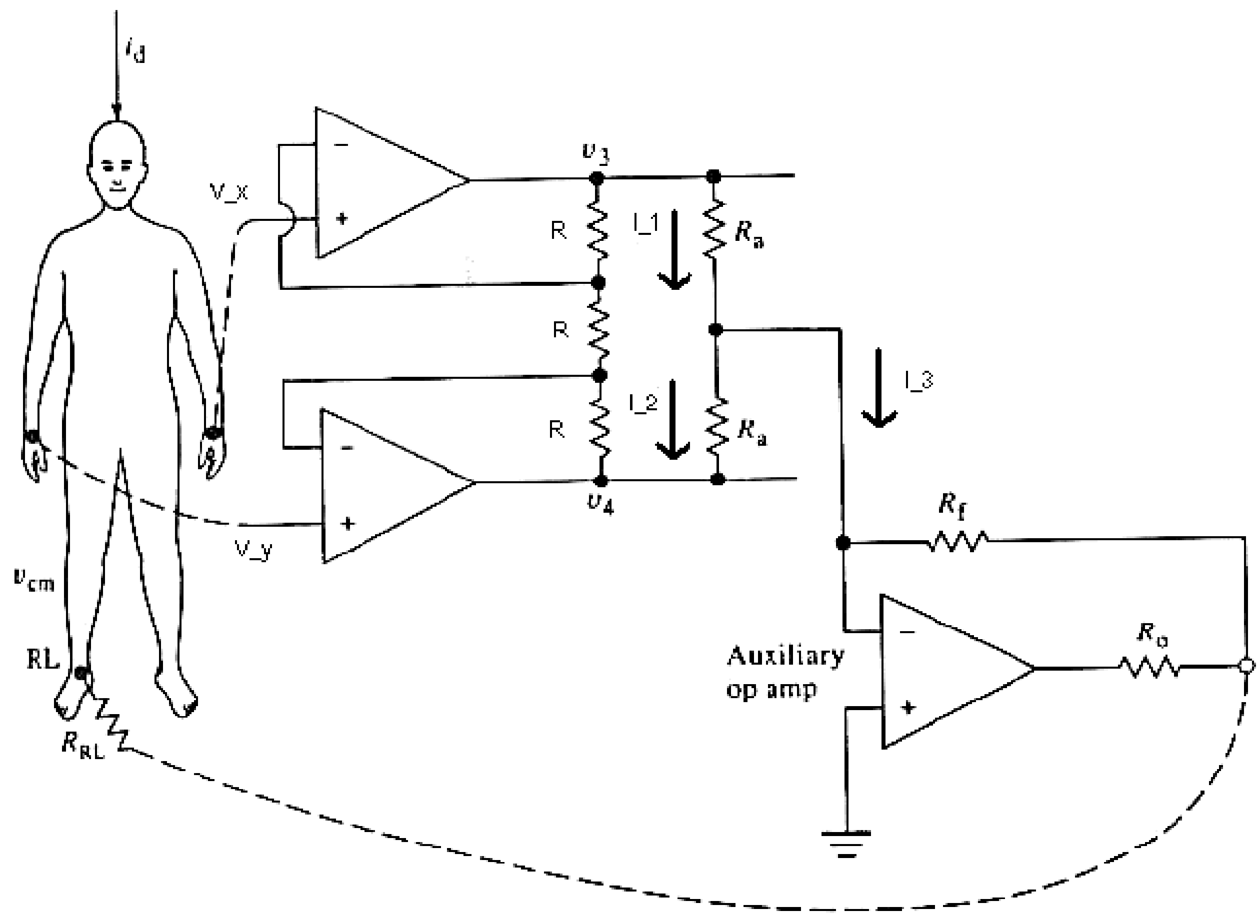
- A **Driven Right Leg circuit** or **DRL** circuit, also known as **Right Leg Driving technique**, is an electric circuit that is often added to biological signal amplifiers to reduce common-mode interference. Biological signal amplifiers such as ECG (electrocardiogram) EEG (electroencephalogram) or EMG circuits measure very small electrical signals emitted by the body, often as small as several micro-volts (millionths of a volt).

Right leg driven ECG amplifier

- Unfortunately, the patient's body can also act as an antenna which picks up electromagnetic interference, especially 50/60 Hz noise from electrical power lines. This interference can obscure the biological signals, making them very hard to measure. Right leg driver circuitry is used to eliminate interference noise by actively cancelling the interference

Right leg driven ECG amplifier

- By convention, lead I has the positive electrode on the **left** arm, and the negative electrode on the **right** arm, and therefore measures the potential difference between the two arms. In this and the other two limb leads, an electrode on the **right leg** serves as a reference electrode for recording purposes.

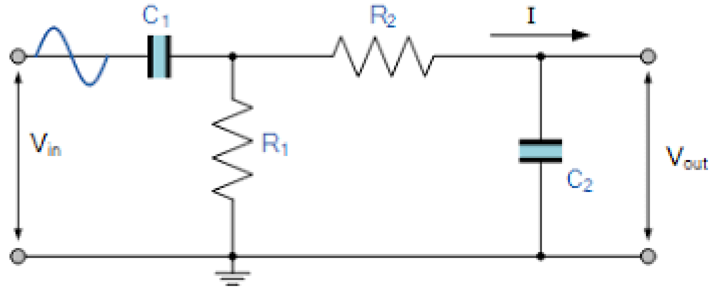


i_d
v_3
V_x
R
I_1
R_a
R
I_3
I_2
R
R_a
v_4
V_y
R_f
v_cm
R_o
RL
Auxiliary
op amp
R_RL

Band pass filtering

- A **band-pass filter** or **bandpass filter** (**BPF**) is a device that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range

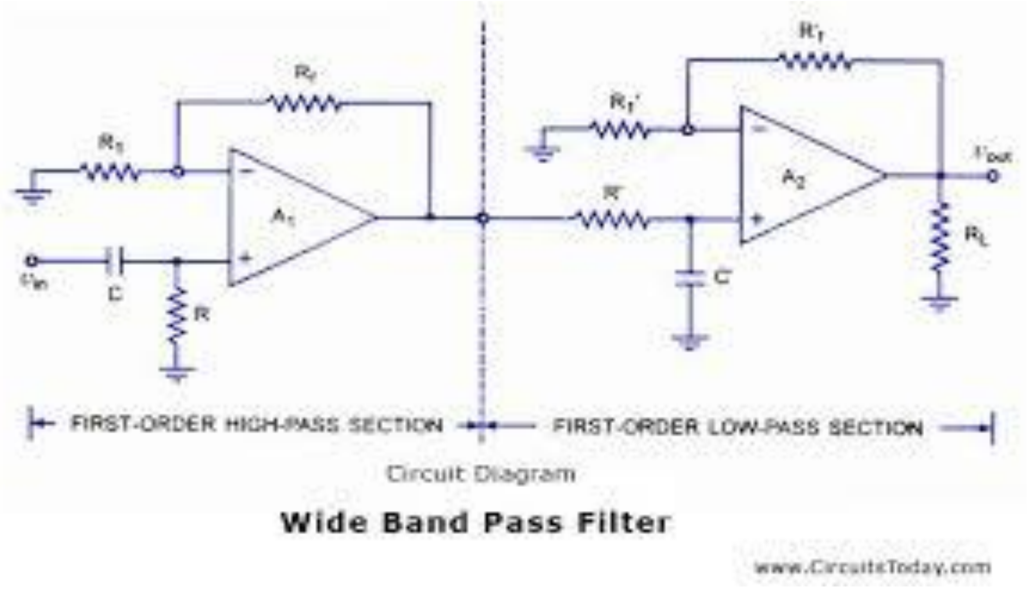
Band pass filtering circuit



Types of BPF

- Wide BPF
- Narrow BPF

Wide BPF



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Wide Band Pass Filter
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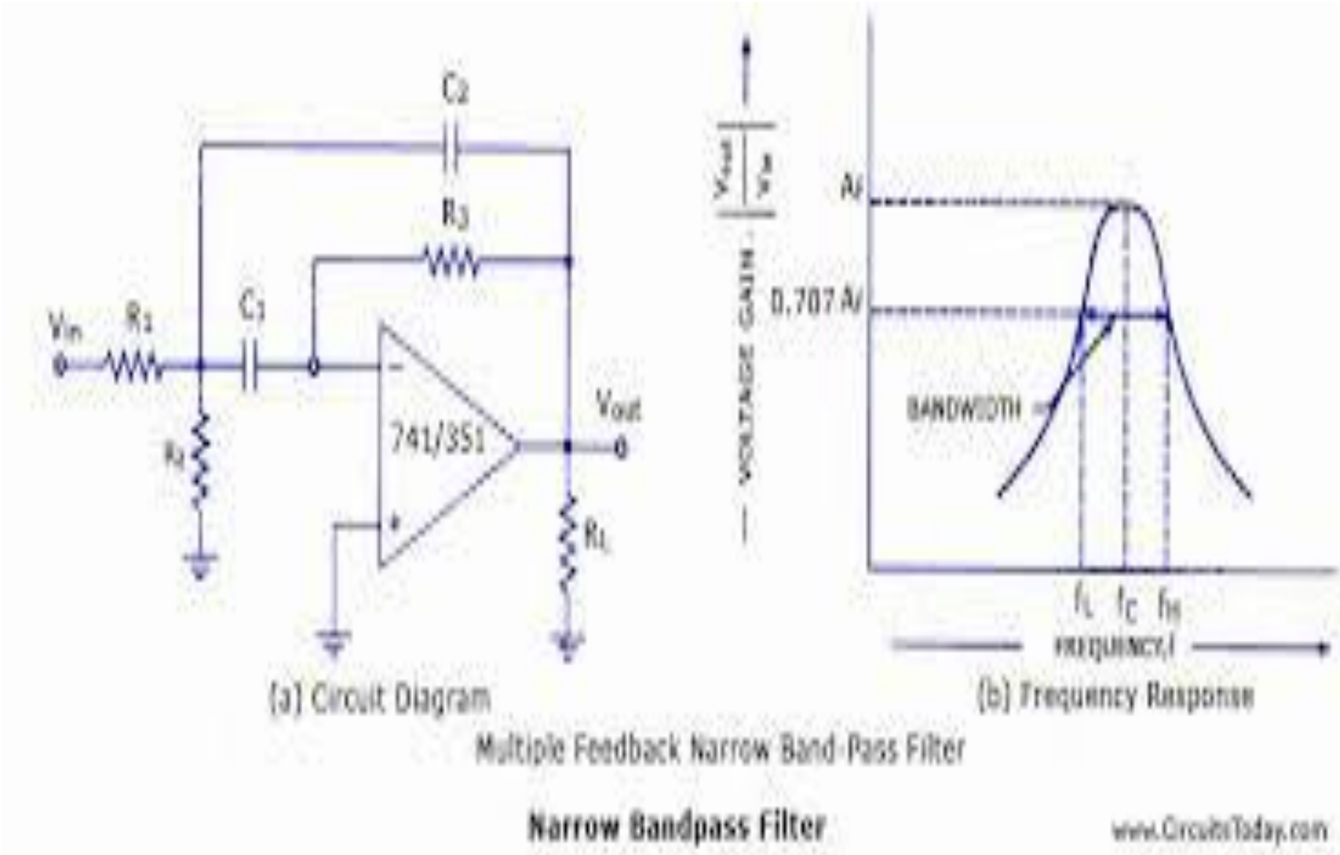
Narrow BPF


C2
R3
Vin
R1
C1
R2
741/351
Vout
RL
(a) Circuit Diagram
VOLTAGE GAIN
Af
0.707 Af
BANDWIDTH
fL
fC
fH
FREQUENCY,f
(b) Frequency Response
Multiple Feedback Narrow Band-Pass Filter
Narrow Bandpass Filter
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