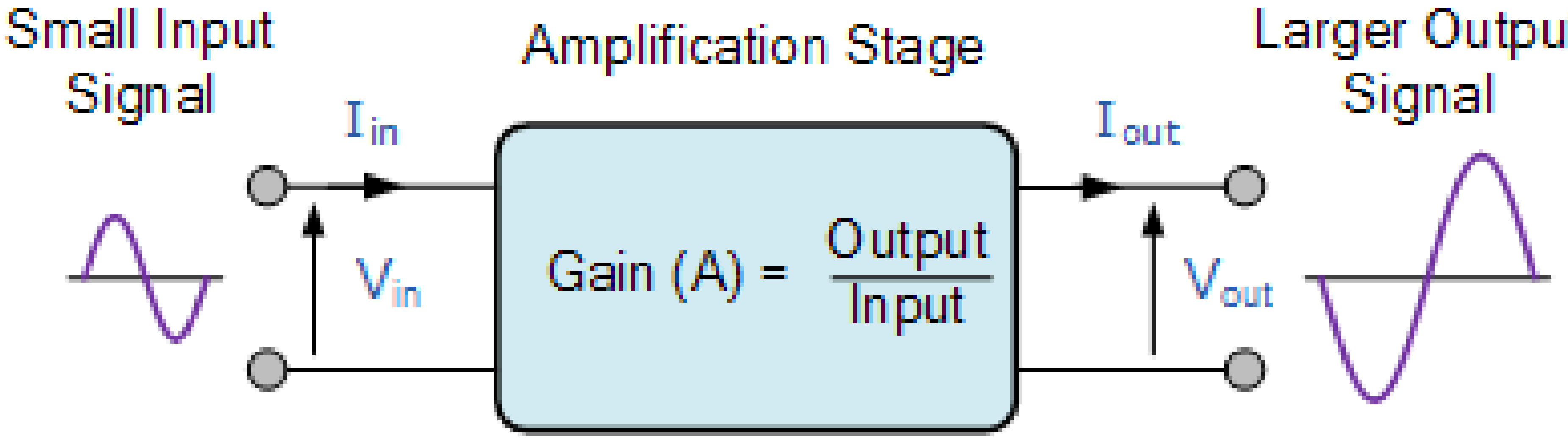
Amplifier is the generic term used to describe a circuit which produces and increased version of its input signal. However, not all amplifier circuits are the same as they are classified according to their circuit configurations and modes of operation.

In “Electronics”, small signal amplifiers are commonly used devices as they have the ability to amplify a relatively small input signal, for example from a Sensor such as a photo-device, into a much larger output signal to drive a relay, lamp or loudspeaker for example.



Voltage Amplifier Gain $$Voltage\,Gain\,(A_v) = \frac{Output\ Voltage}{Input\ Voltage} = \frac{Vout}{Vin}$$

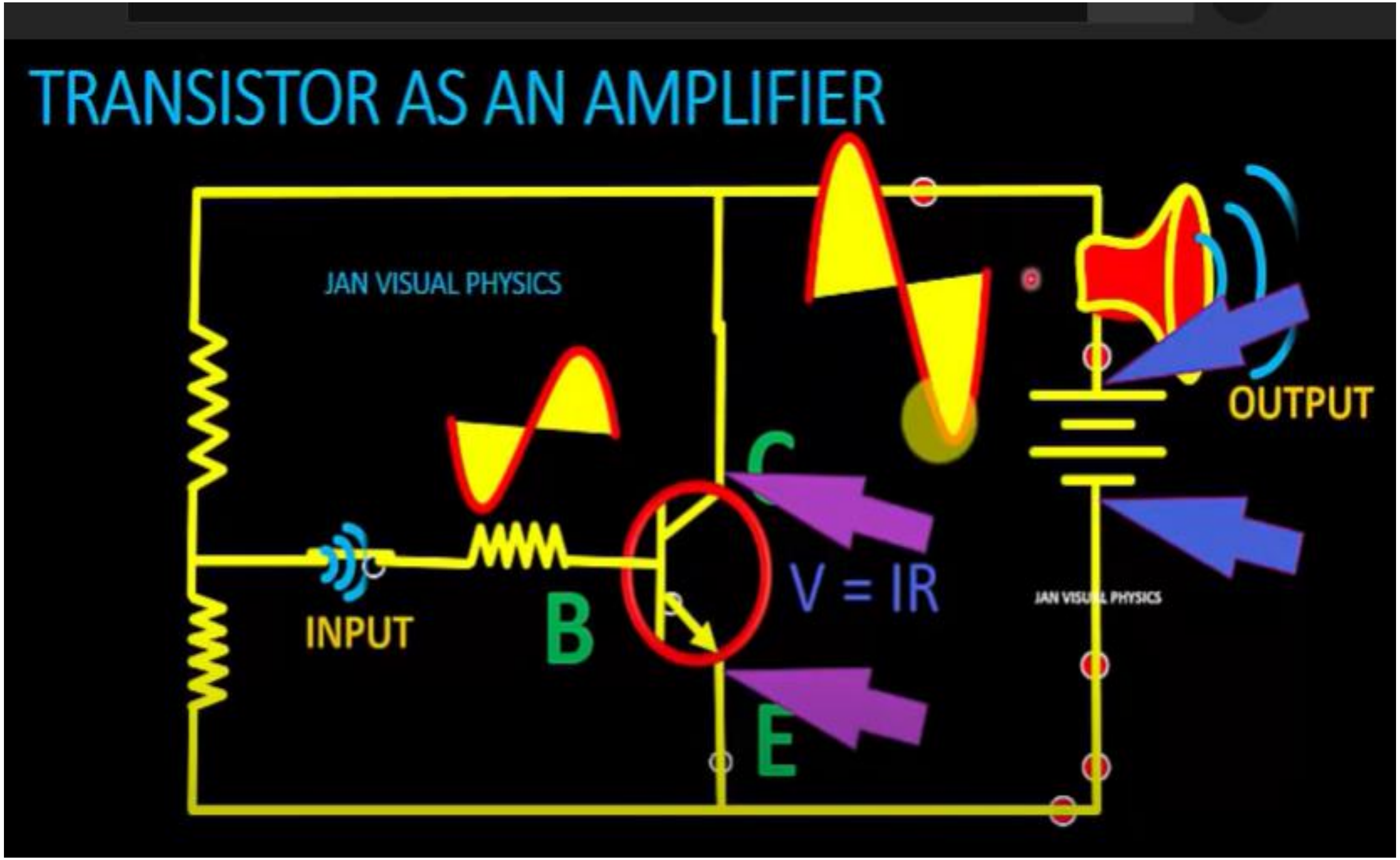
Current Amplifier Gain $$Current\,Gain\,(A_i) = \frac{Output\ Current}{Input\ Current} = \frac{Iout}{Iin}$$

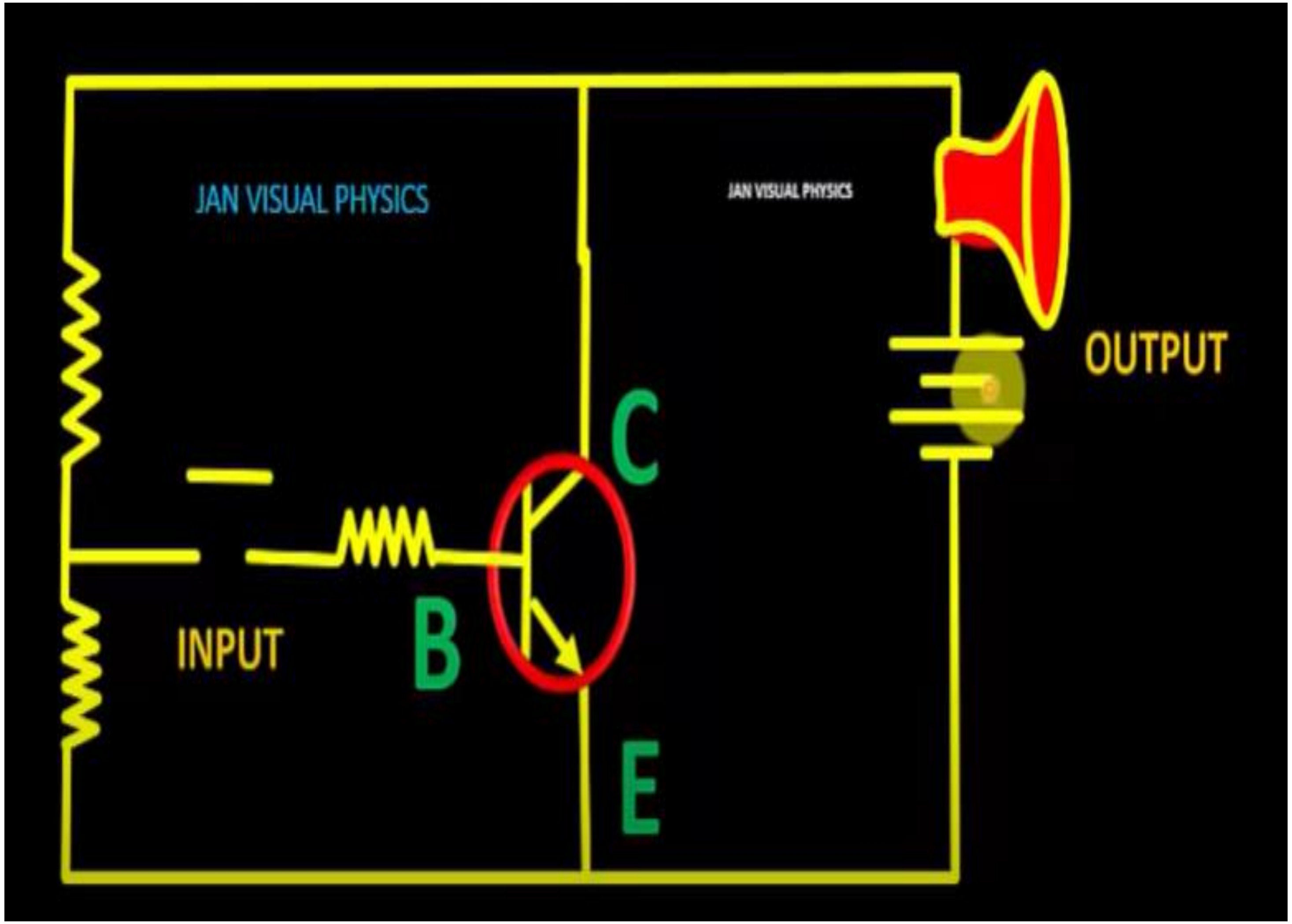
Power Amplifier Gain $$Power\,Gain\,(A_p) = A_v \ x \ A_i$$

The introduction to the amplifier gain can be said to be the relationship that exists between the signal measured at the output with the signal measured at the input. There are three different kinds of amplifier gain which can be measured and these are: Voltage Gain (Av), Current Gain (Ai) and Power Gain (Ap) depending upon the quantity being

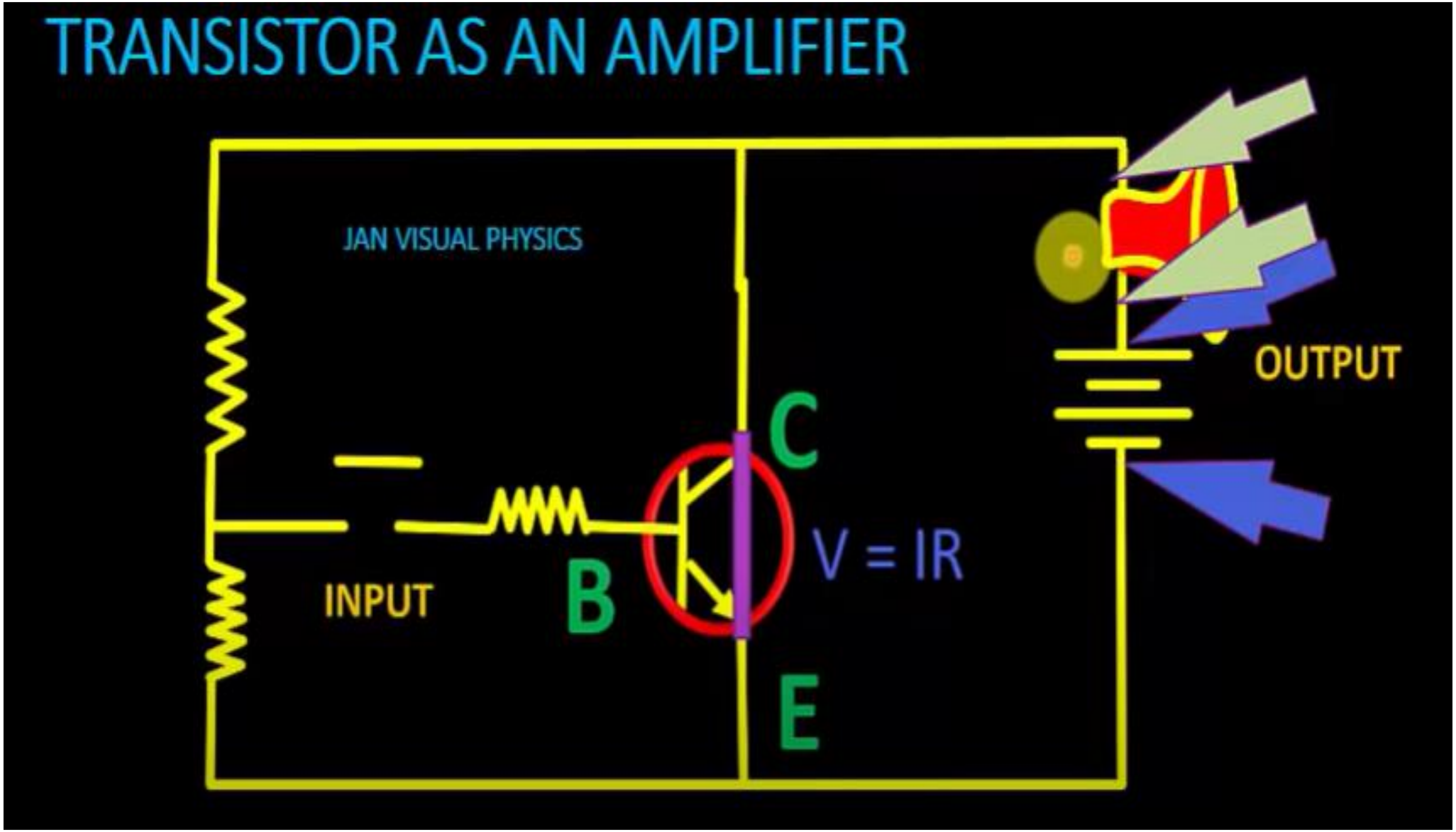
	DC gains	AC gains
Voltage	$A_V = \frac{V_{output}}{V_{input}}$	$A_V = \frac{\Delta V_{output}}{\Delta V_{input}}$
Current	$A_I = \frac{I_{output}}{I_{input}}$	$A_I = \frac{\Delta I_{output}}{\Delta I_{input}}$
Power	$A_P = \frac{P_{output}}{P_{input}}$	$A_P = \frac{(\Delta V_{output})(\Delta I_{output})}{(\Delta V_{input})(\Delta I_{input})}$
	$A_P = (A_V)(A_I)$	

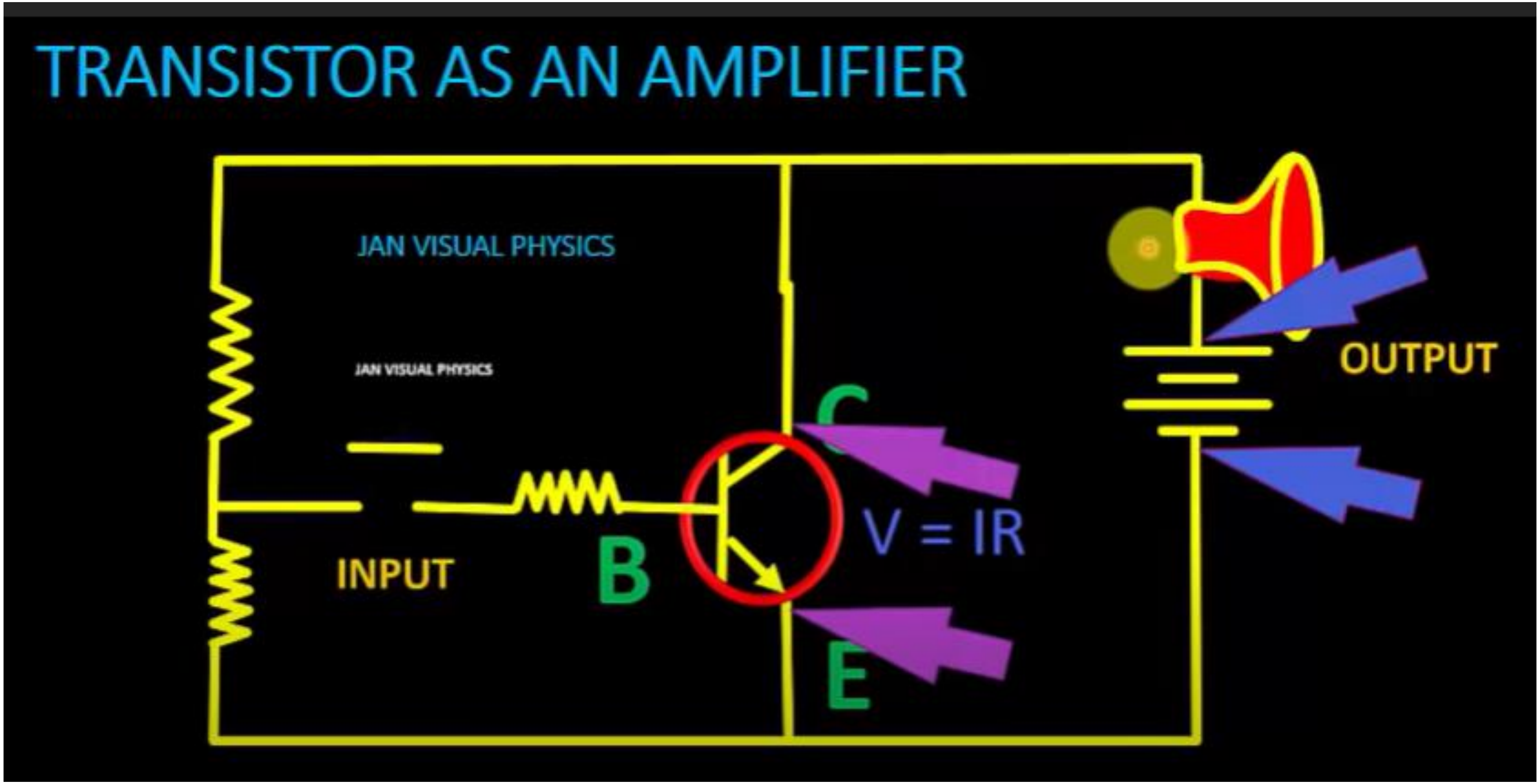
Δ = *"change in . . ."*

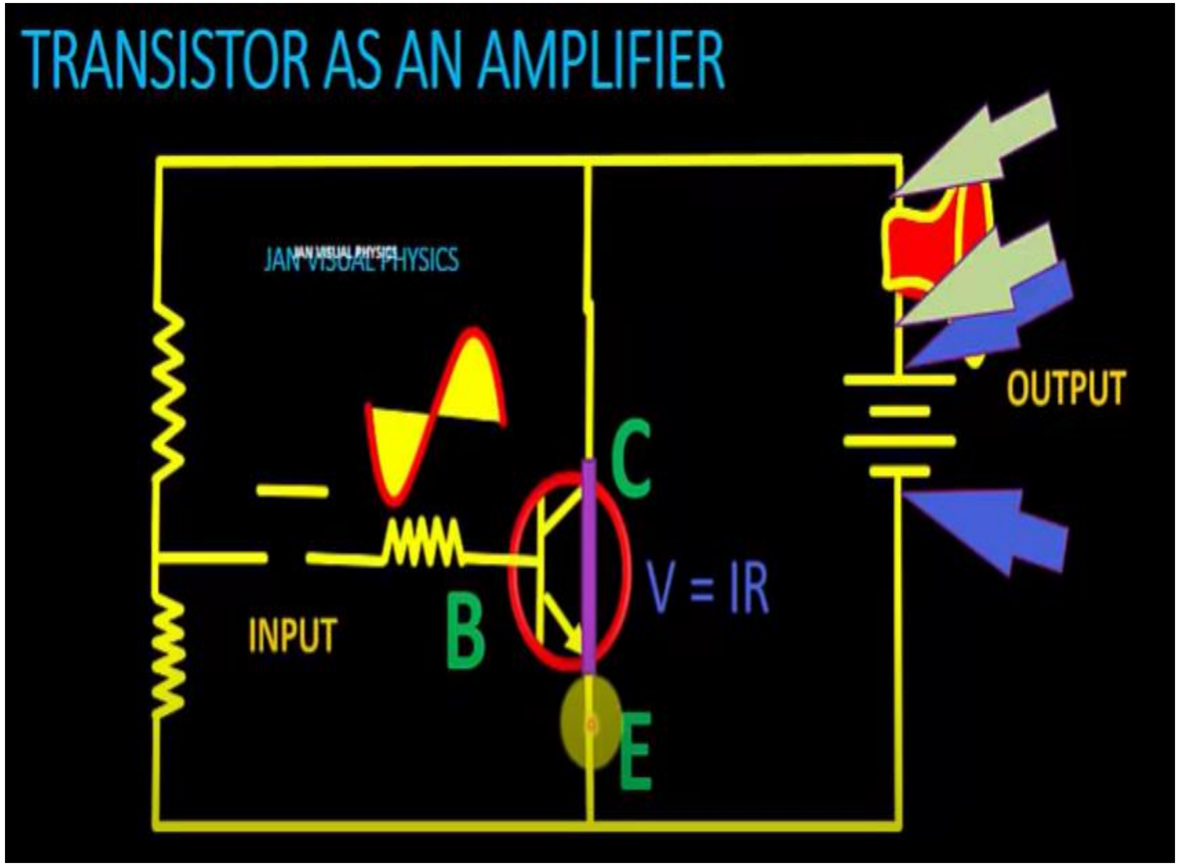

TRANSISTOR AS AN AMPLIFIER
JAN VISUAL PHYSICS
OUTPUT
C
V = IR
B
INPUT
E
JAN VISUAL PHYSICS



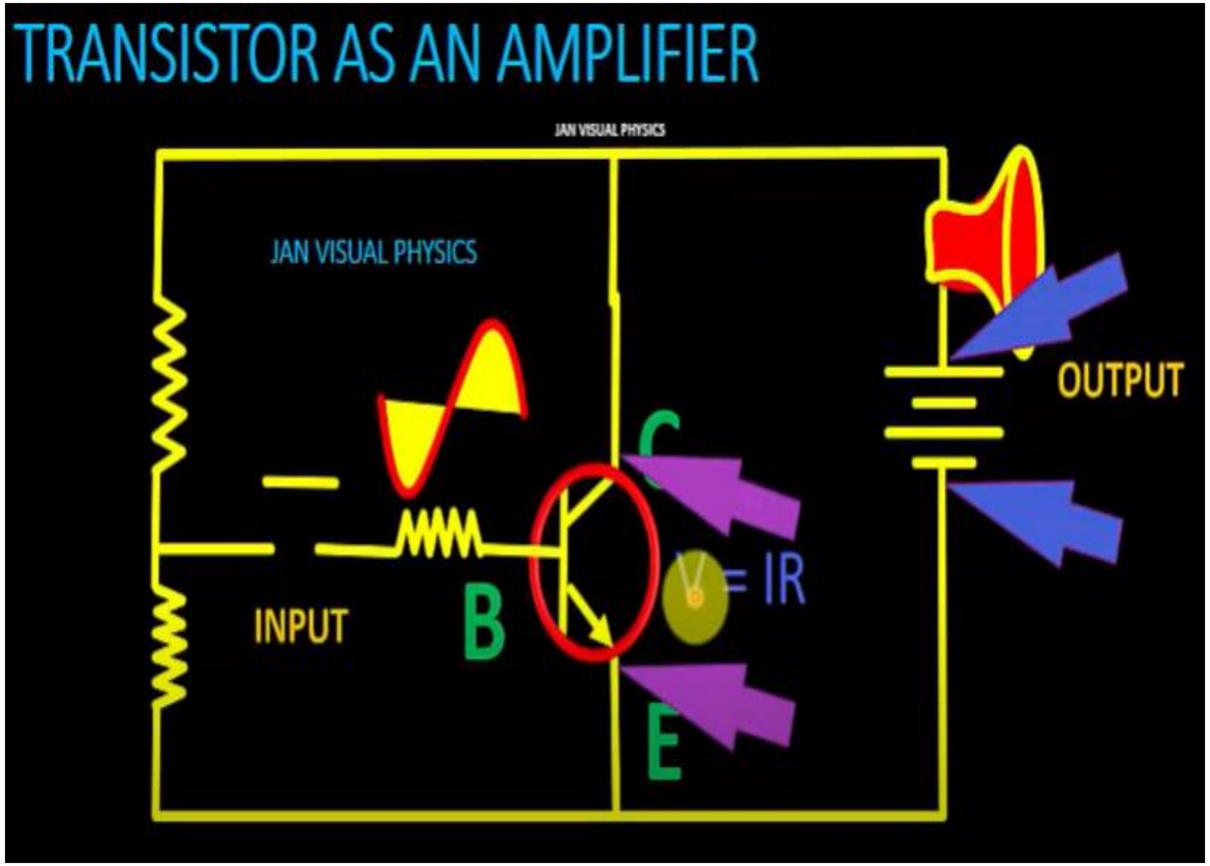
JAN VISUAL PHYSICS
JAN VISUAL PHYSICS
OUTPUT
C
B
INPUT
E


TRANSISTOR AS AN AMPLIFIER
JAN VISUAL PHYSICS
OUTPUT
C
INPUT
B
V = IR
E

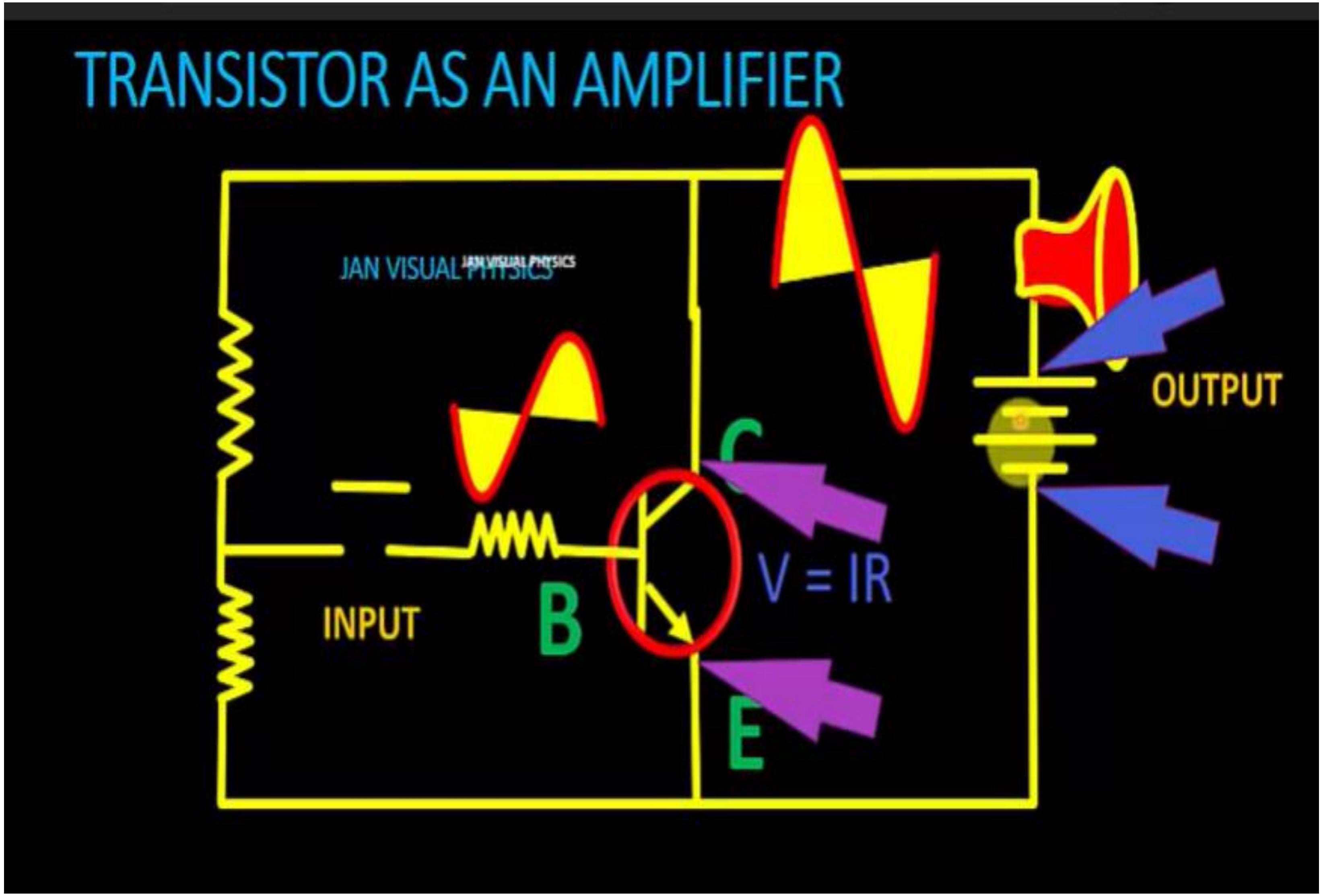

TRANSISTOR AS AN AMPLIFIER
JAN VISUAL PHYSICS
JAN VISUAL PHYSICS
C
OUTPUT
V = IR
INPUT
B
E

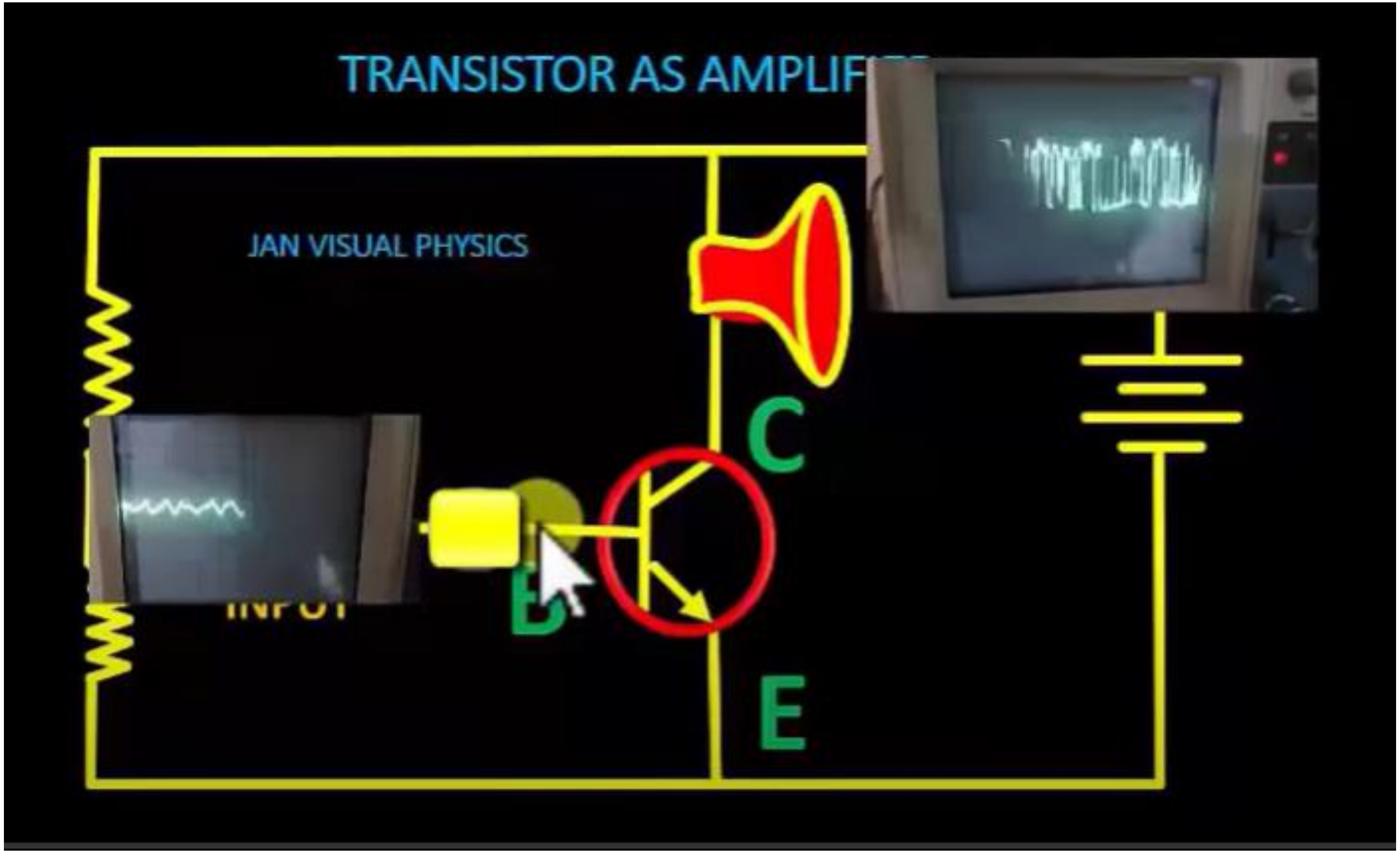


TRANSISTOR AS AN AMPLIFIER
JAN VISUAL PHYSICS
OUTPUT
C
V = IR
B
INPUT
E



TRANSISTOR AS AN AMPLIFIER
JAN VISUAL PHYSICS
JAN VISUAL PHYSICS
OUTPUT
C
V = IR
B
INPUT
E

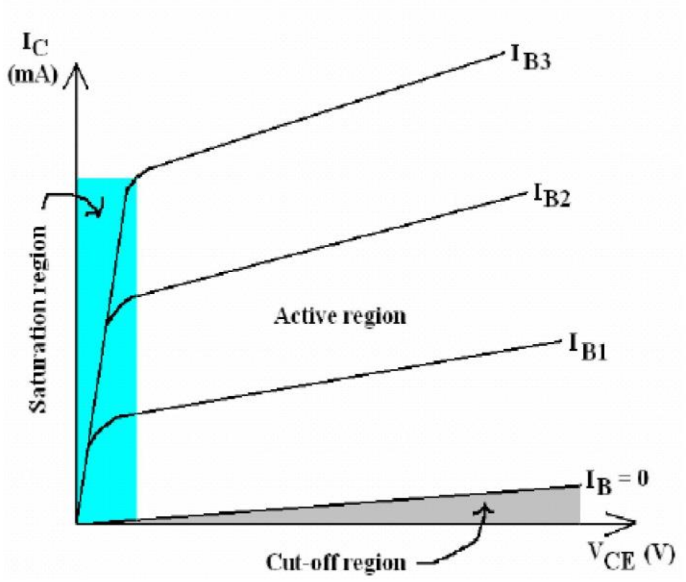

TRANSISTOR AS AN AMPLIFIER
JAN VISUAL PHYSICS
OUTPUT
C
B
INPUT
V = IR
E



TRANSISTOR AS AMPLIF
JAN VISUAL PHYSICS
C
B
E

CE output characteristics

– A plot of I_C *versus* V_{CE} *for various values of IB*
– Three regions identified:
Active,
Cut-off,
Saturation



– <u>Active region</u>:

- Linear region in the output characteristics
- E-B junction forward biased
- C-B junction reverse biased
- I_C *increases with* I_B

– <u>Cut off region</u>:

Region below $I_B=0$ *line (or* $I_C=I_{CEO}$*)*

– <u>Saturation Region</u>:

Region to the left of the vertical line $V_{CE}=V_{CE}(sat)=0.3V$ *(for Silicon)*

Transistor Biasing

- Applying external dc voltages to ensure that transistor operates in the desired region

- Which is the desired region?

– For amplifier application, transistor should operate in active region

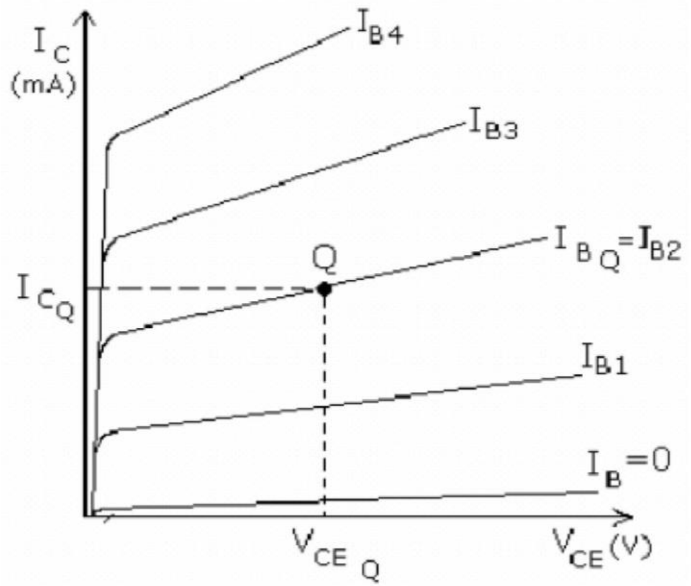
– For switch application, it should operate in cut-off and sat.

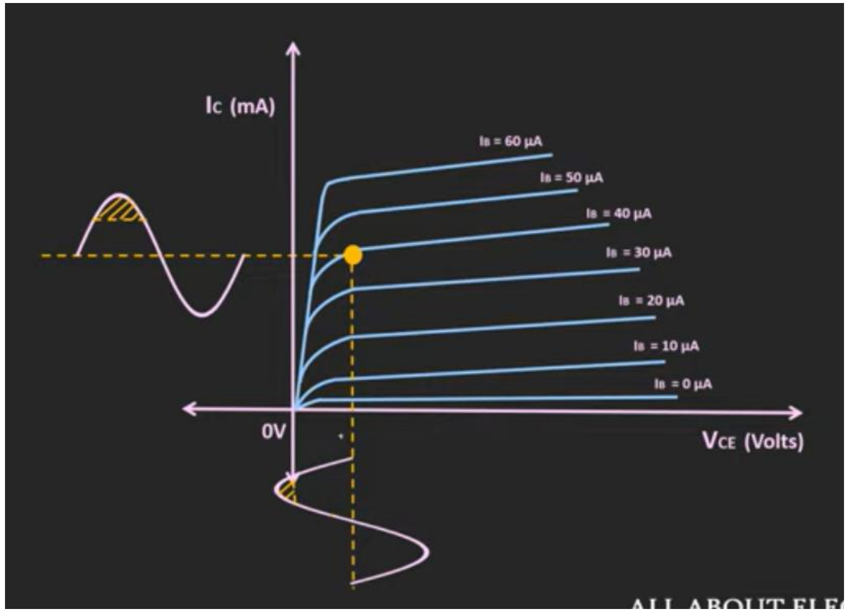
Quiescent Operating Point or Q-point

- Establishing the correct operating point requires the selection of bias resistors and load resistors to provide the appropriate input current and collector voltage conditions.

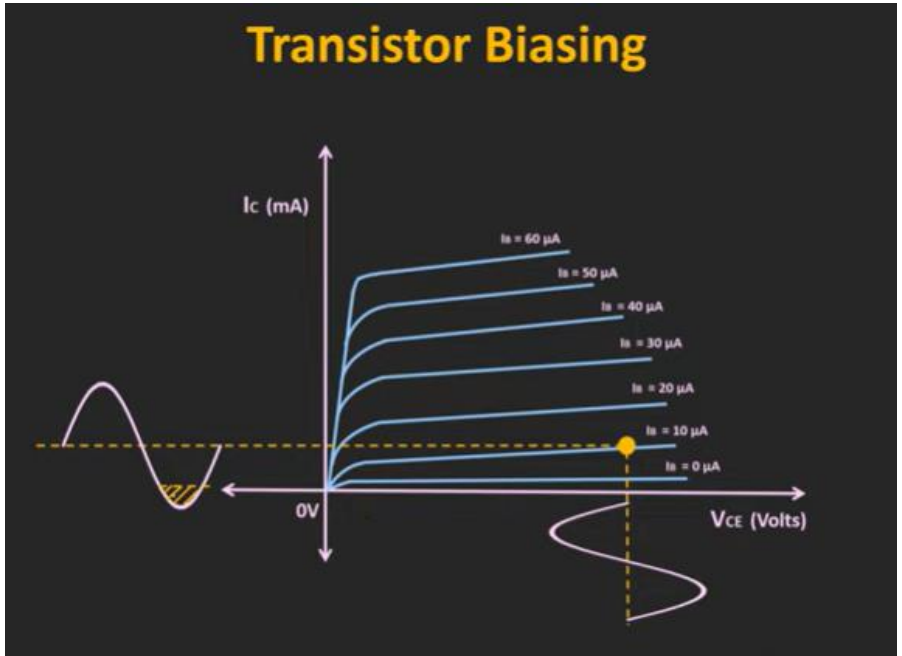
- The correct biasing point for a bipolar transistor, either NPN or PNP, generally lies somewhere between the two extremes of operation with respect to it being either "fully-ON" or "fully-OFF" along its DC load line.

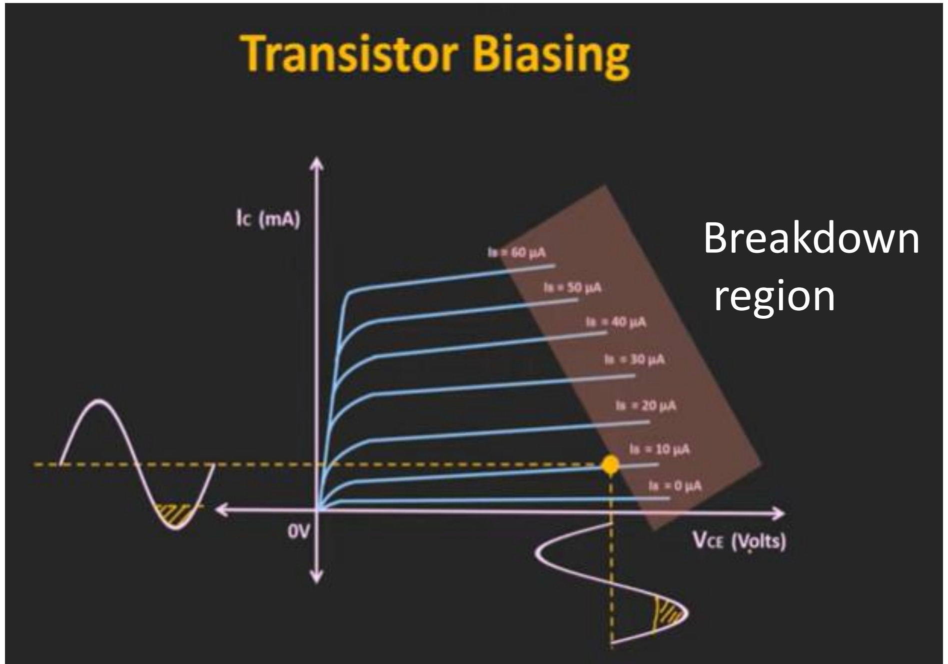
- This central operating point is called the "Quiescent Operating Point", or **Q-point** for short

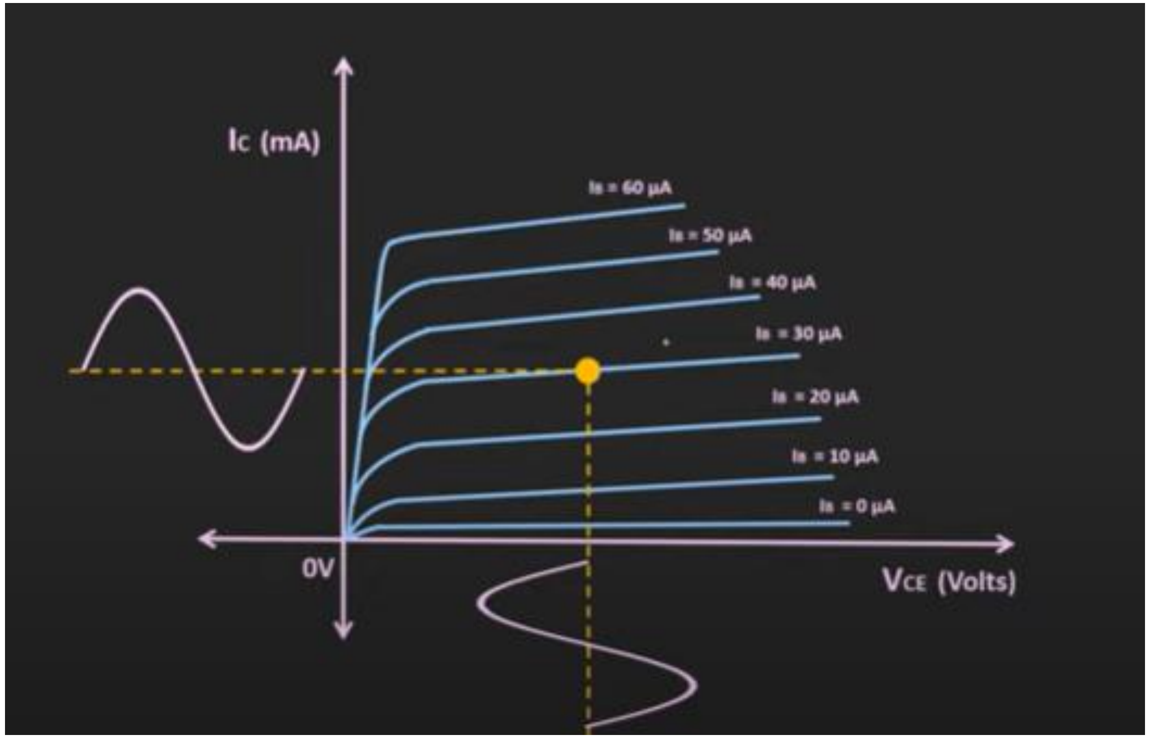




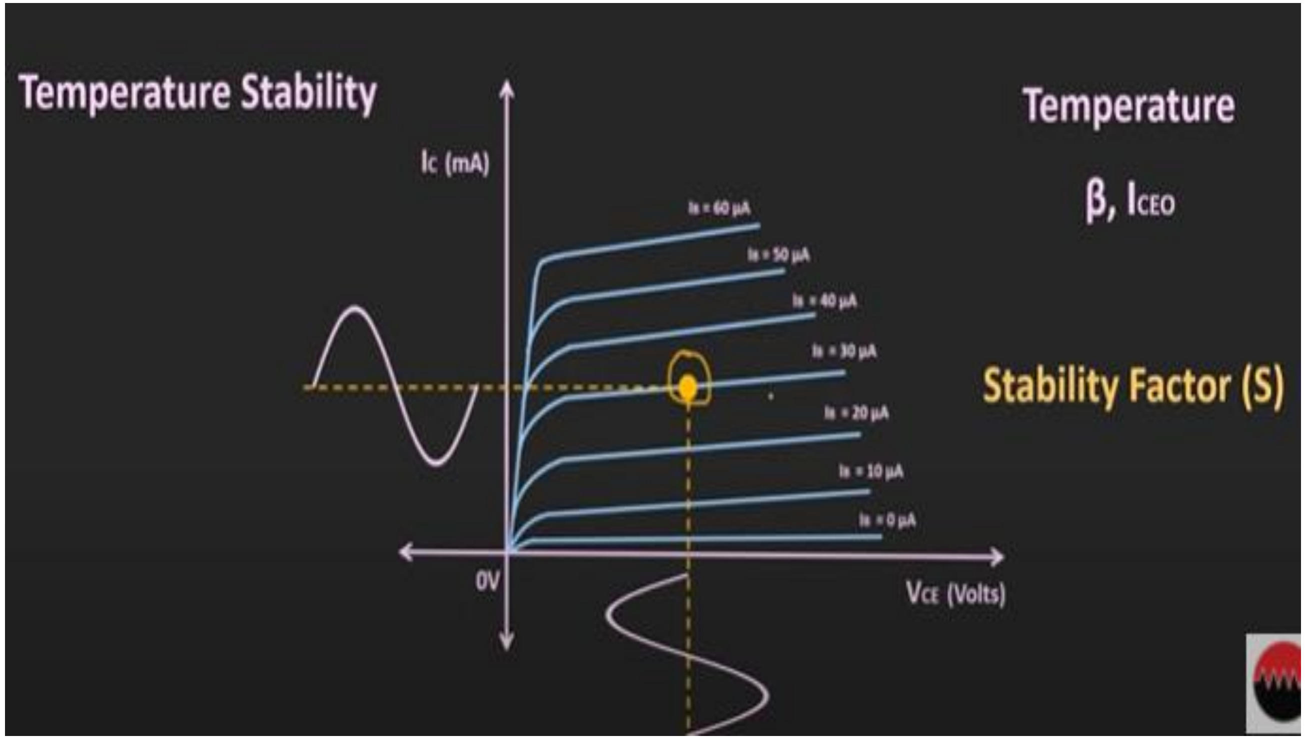
Because collector current cannot go beyond Zero ampere
And due that some portion of the voltage Vce will also get clipped







Ic (mA)
IB = 60 μA
IB = 50 μA
IB = 40 μA
IB = 30 μA
IB = 20 μA
IB = 10 μA
IB = 0 μA
0V
VCE (Volts)



Temperature Stability
Temperature
β, ICEO
Stability Factor (S)
Ic (mA)
0V
VCE (Volts)

- <u>Pros:</u>

1) Simple circuit
2) Uses very few resistors

- <u>Cons:</u>

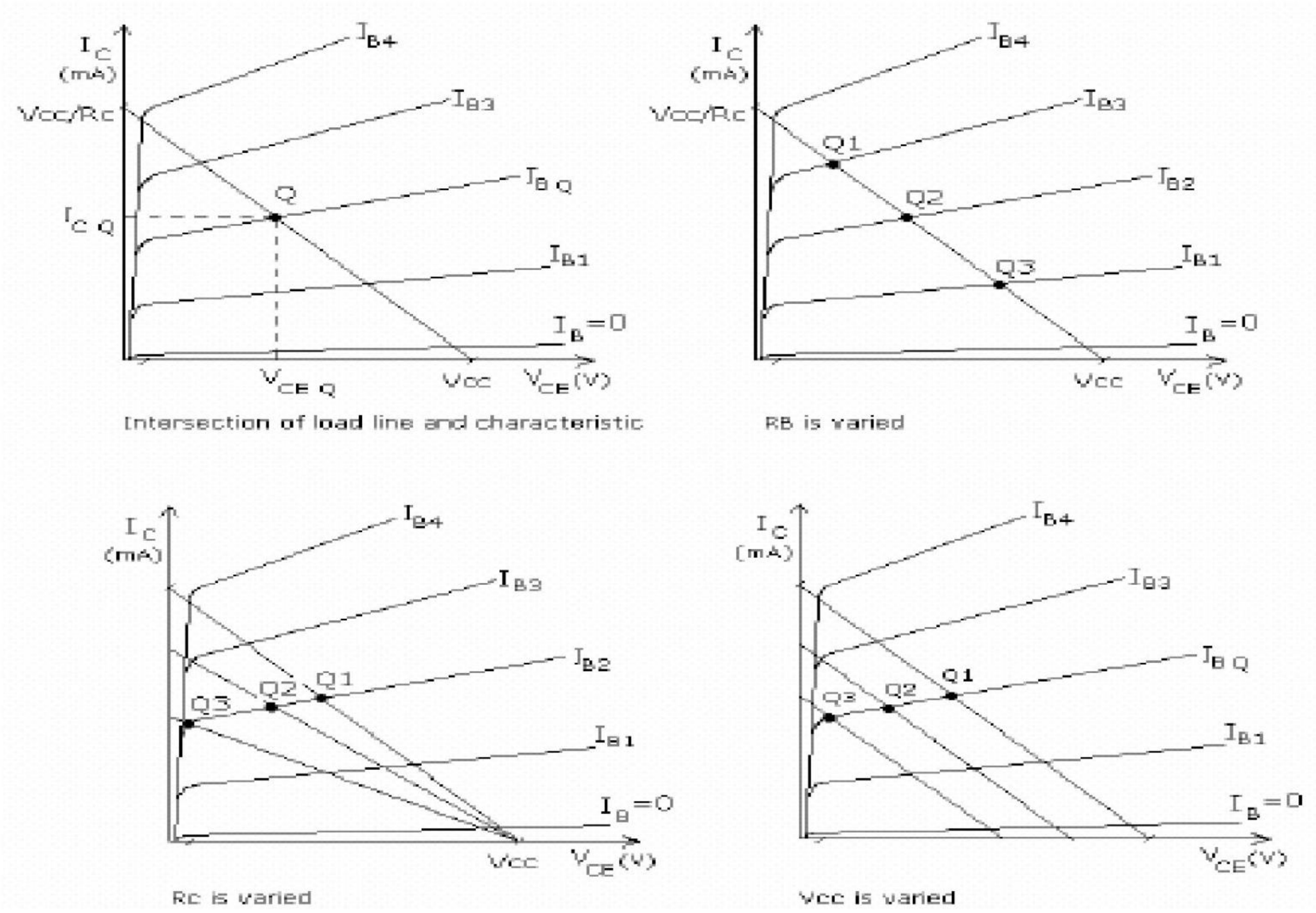
1. Q-point is unstable

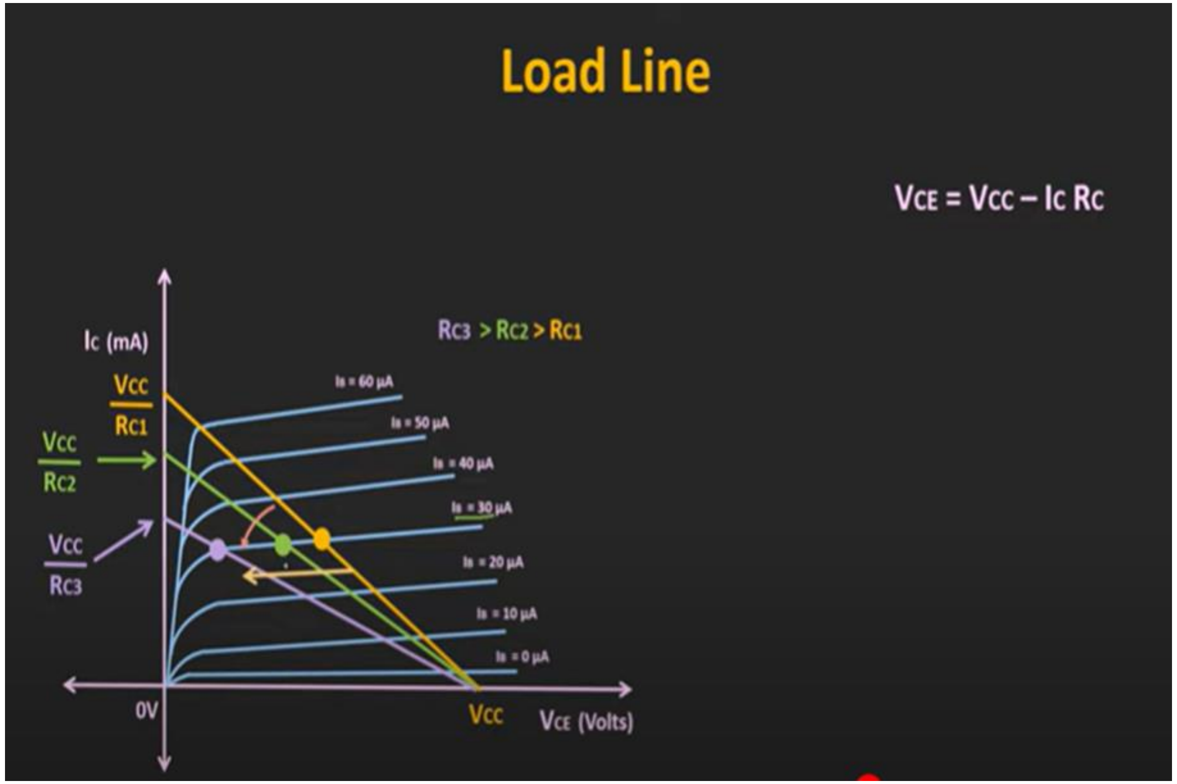
- If temperature increases, then *β increases, and*

hence *I_{CQ} and V_{CEQ} vary (effectively Q-point shifts)*

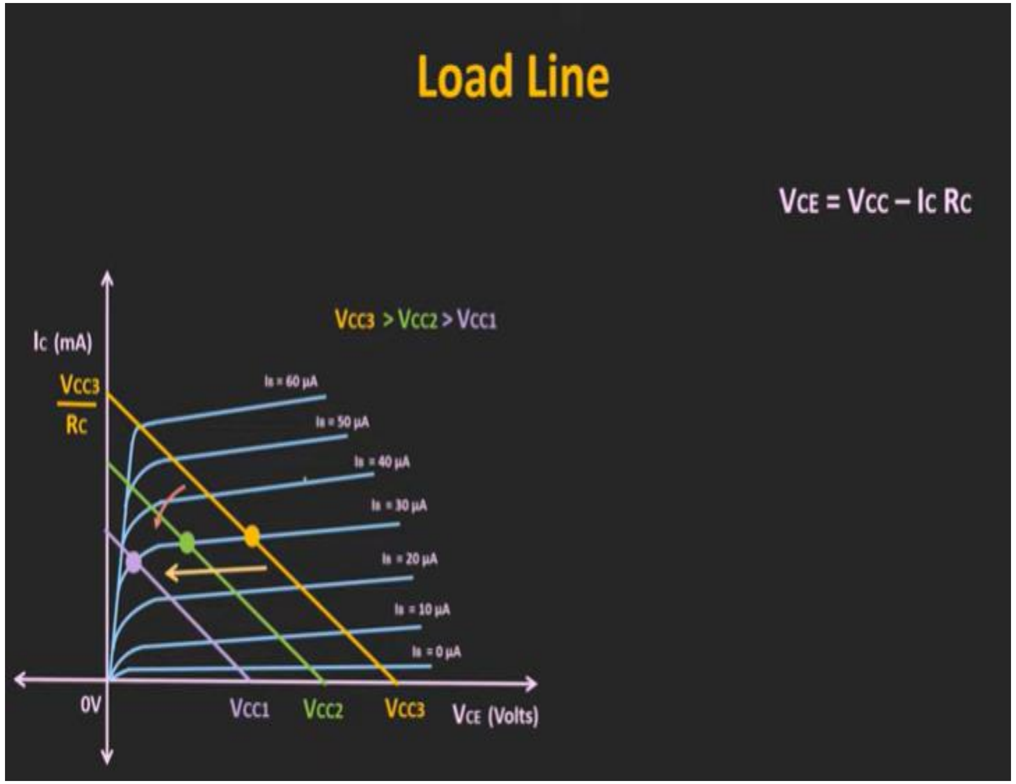
- If the transistor is replaced with another transistor having different *β value, then also Q-point shifts*

Load Line Characteristics: Variation in load line with circuit parameters *VCC, RC* and *RB*





Load Line
VCE = VCC – IC RC
RC3 > RC2 > RC1
IC (mA)
VCC / RC1
VCC / RC2
VCC / RC3
0V
VCC
VCE (Volts)



Load Line
VCE = VCC – IC RC
VCC3 > VCC2 > VCC1
IC (mA)
VCC3 / RC
0V
VCC1
VCC2
VCC3
VCE (Volts)

Classification of Amplifiers

1)Based on Number of stage

I. Single stage amplifier- Single transistor
II. Multi stage amplifier-multi transistor

2)Based on its output

I. Voltage amplifier-increase voltage level input
II. Power amplifier –power level input

3)Based on its input signal

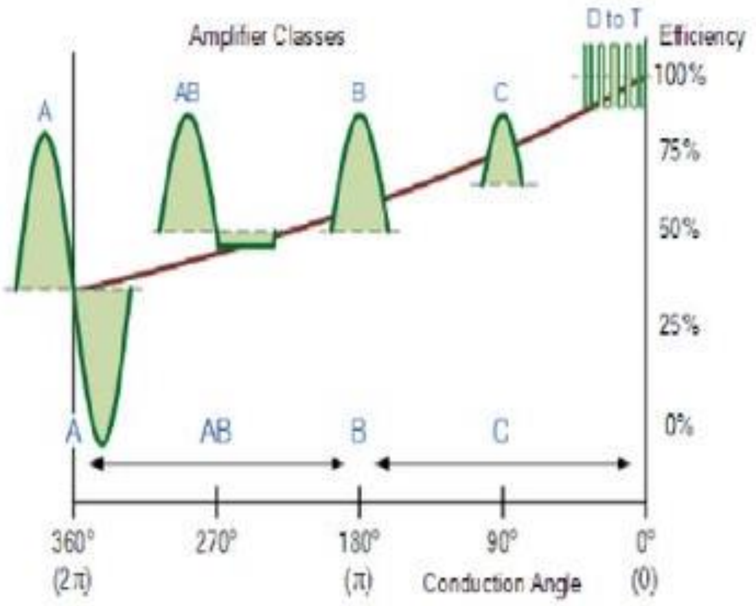
I. Small Signal –small fluctuations in collector current
II. Large signal-fluctuations in collector current is large

4) Based on the frequency

I. Audio-20 Hz to 20Khz
II. power- Very high frequency

5) Based on biasing conditions

I. Class A
II. Class B
III. Class C
IV. Class AB

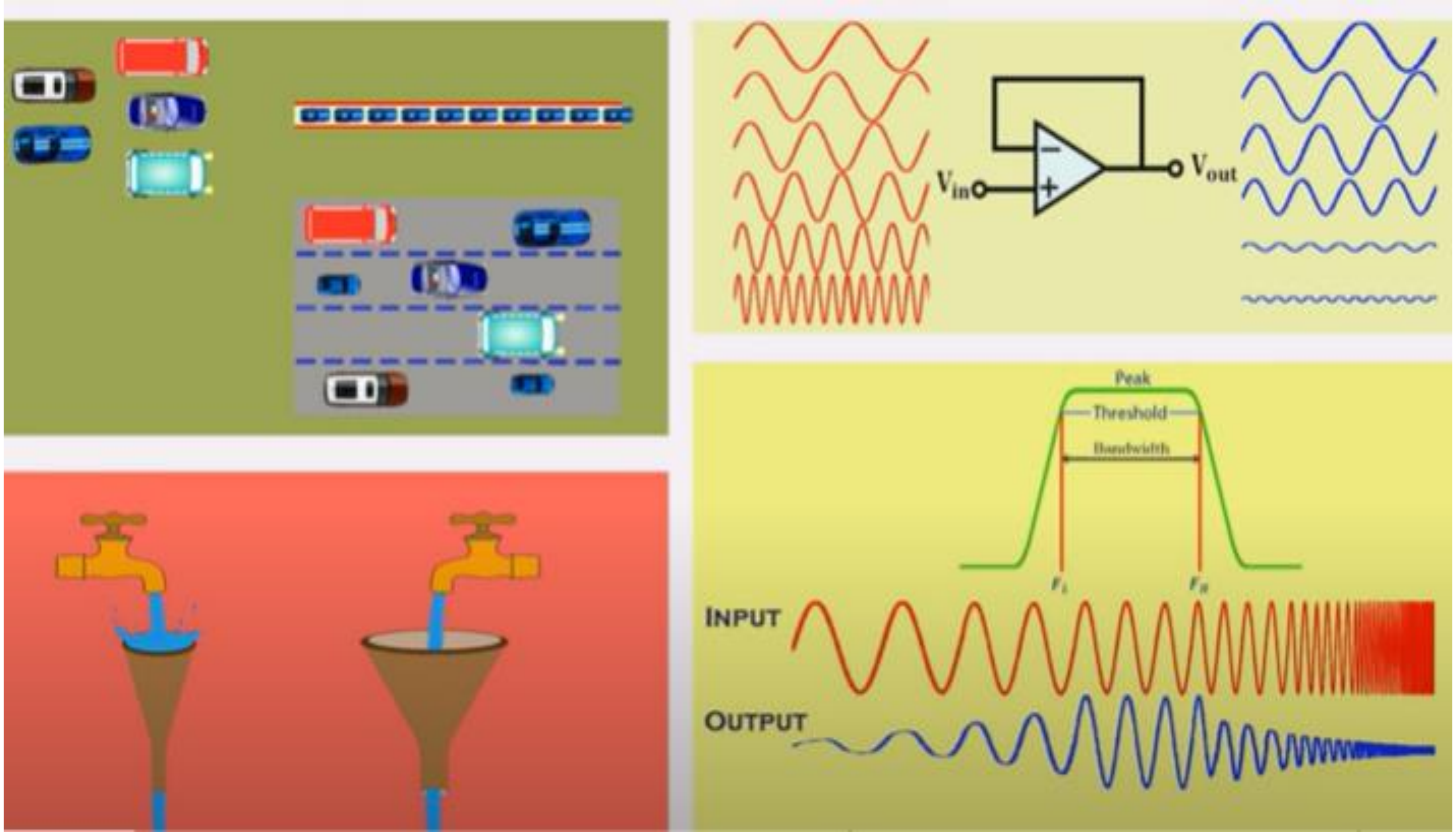


6) Based on coupling methods

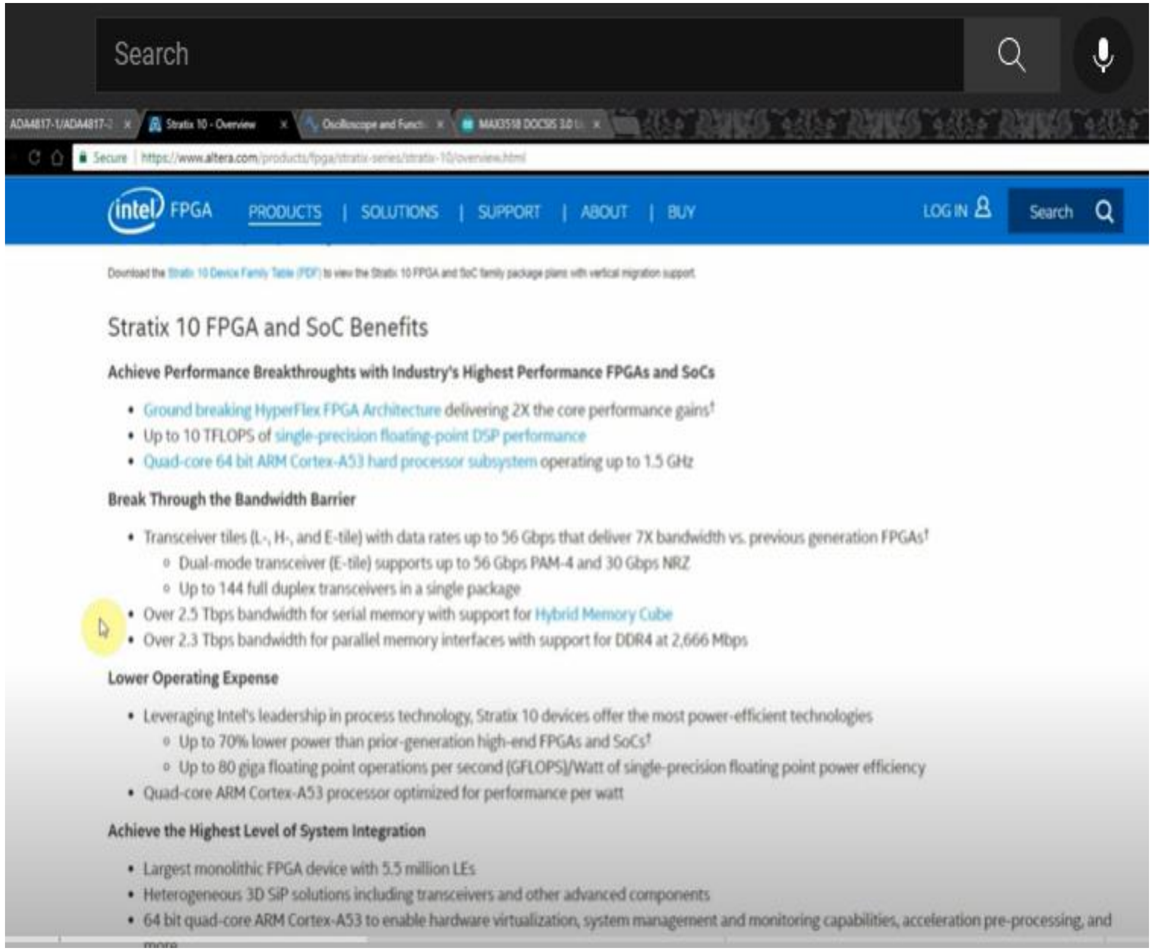
I. RC Coupling (R&C)
II. Transformer (Transformer)
III. Direct coupling (Transistor)

7) Based on its configurations

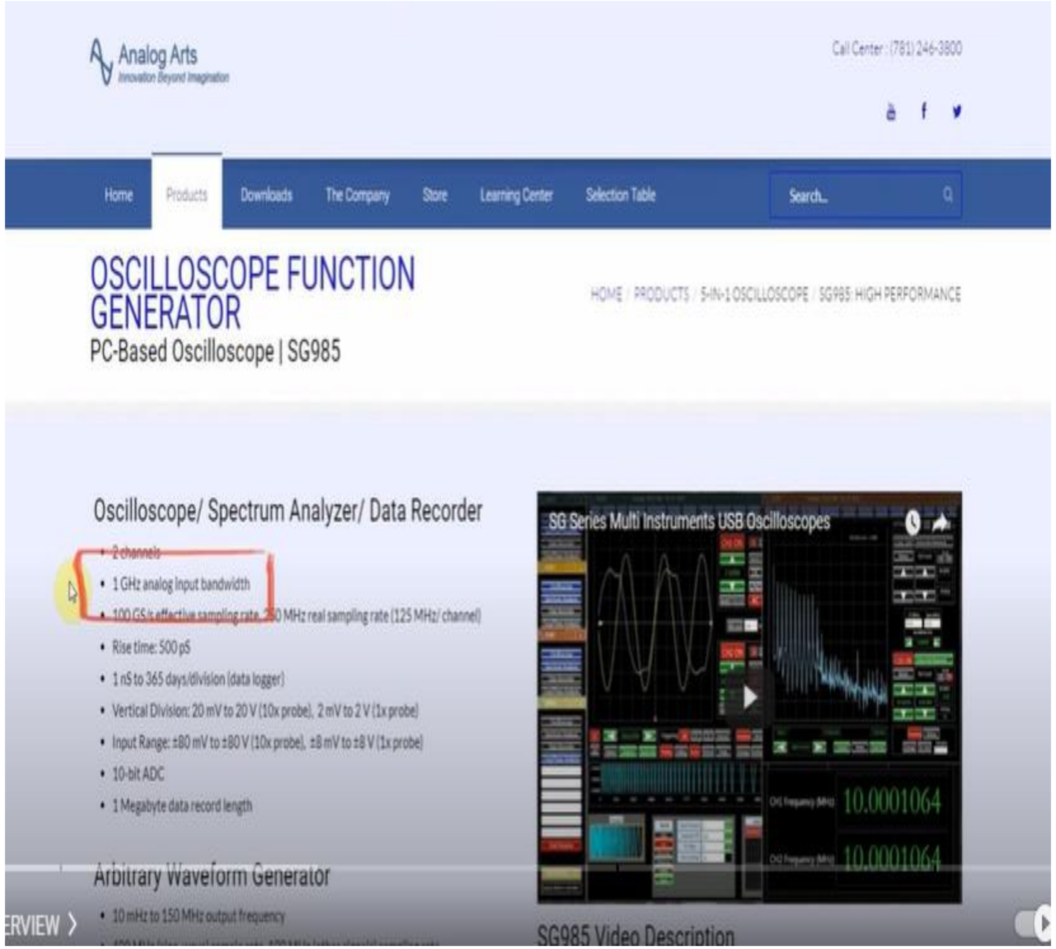
CE,CB,CC



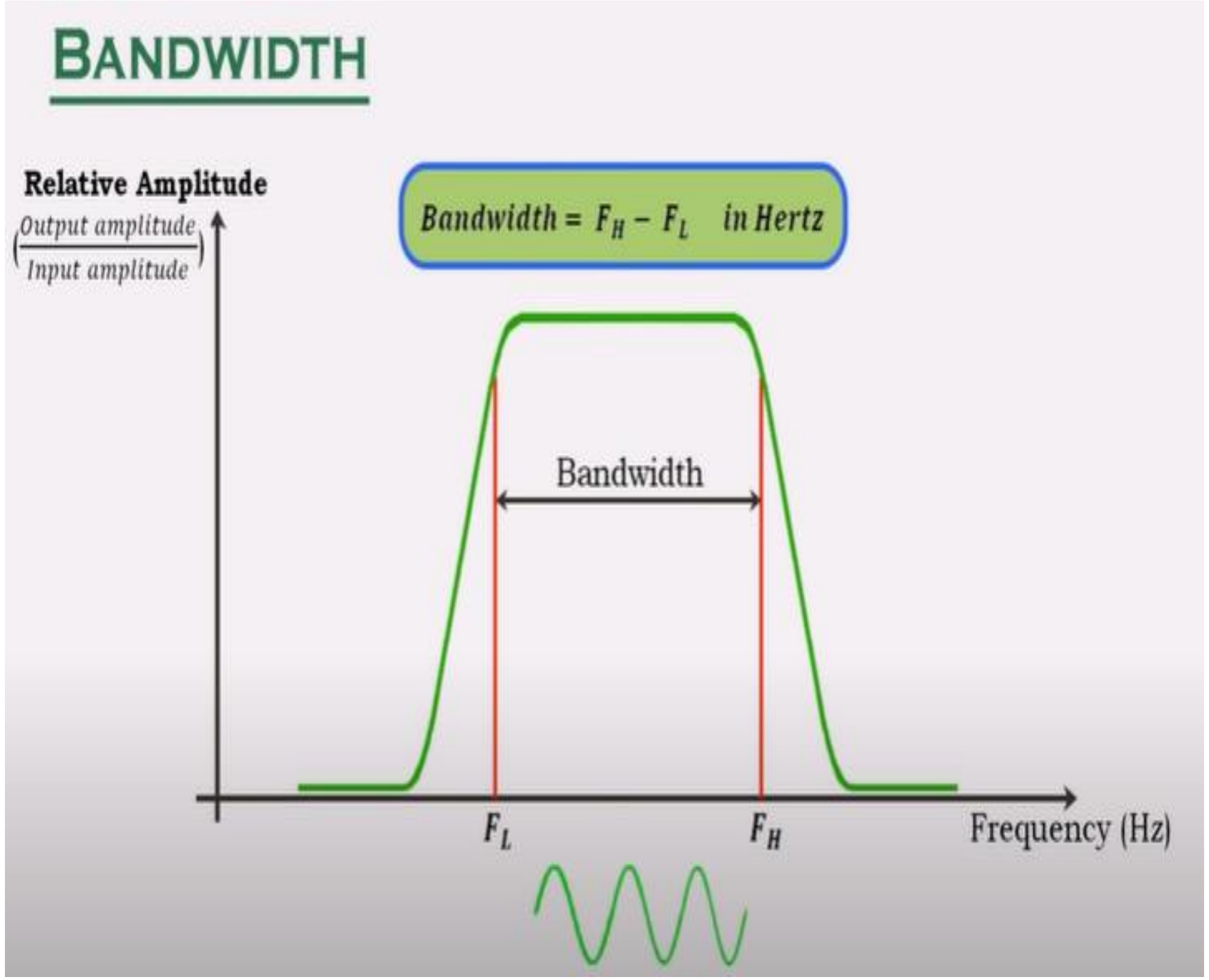
V_{in}
V_{out}
Peak
Threshold
Bandwidth
INPUT
OUTPUT

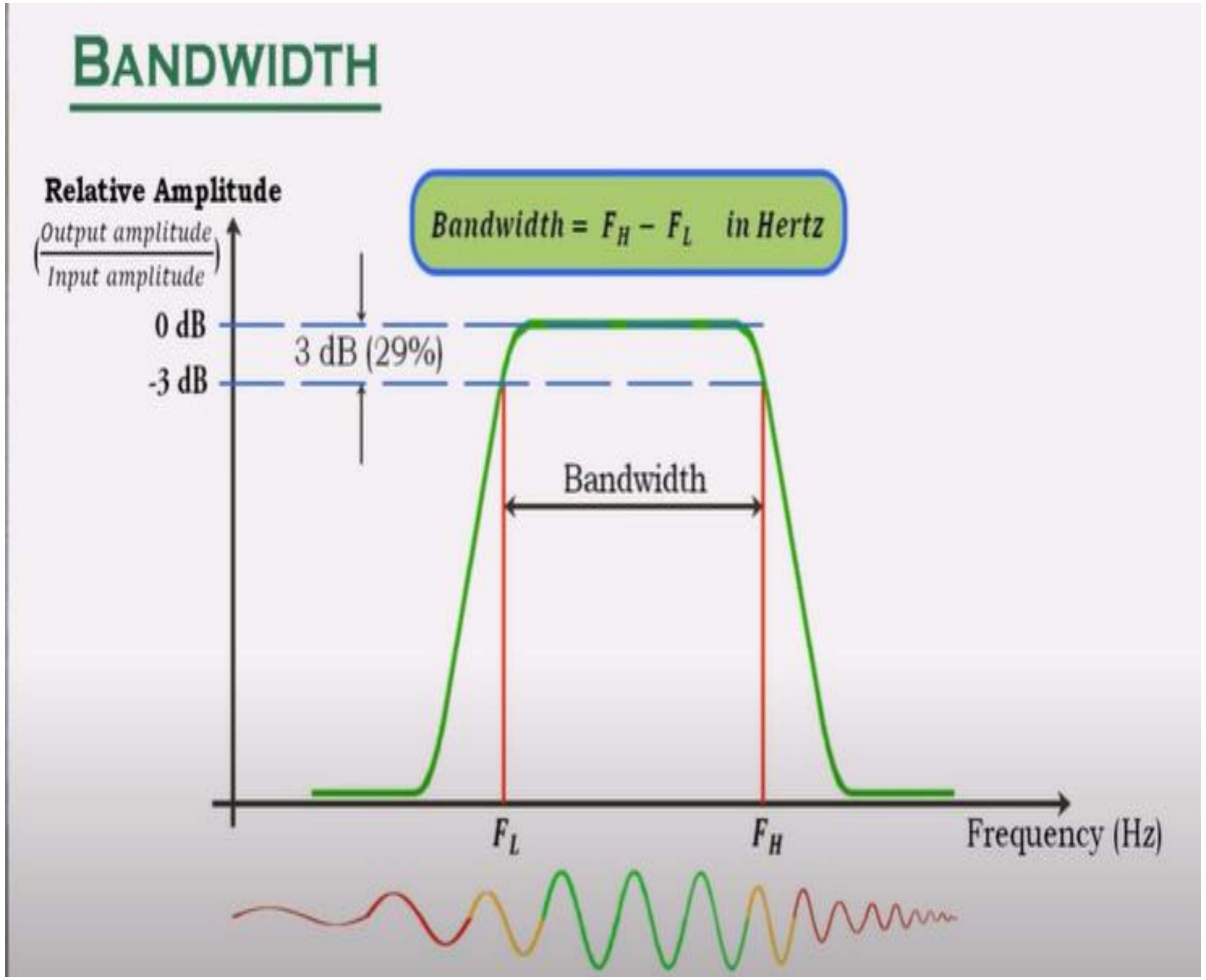


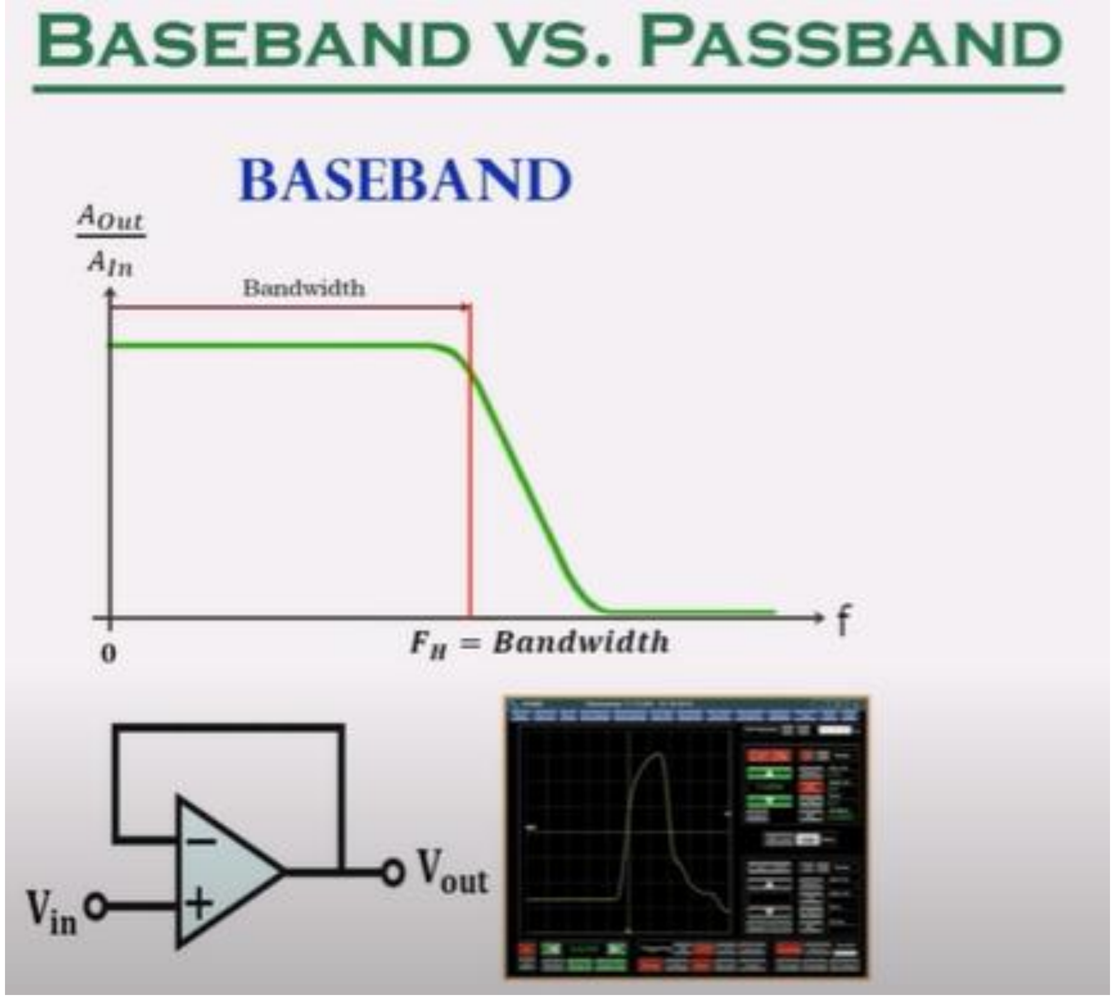
Search
Stratix 10 - Overview
intel FPGA
PRODUCTS | SOLUTIONS | SUPPORT | ABOUT | BUY
LOG IN
Search
Stratix 10 FPGA and SoC Benefits
Achieve Performance Breakthroughts with Industry's Highest Performance FPGAs and SoCs
Ground breaking HyperFlex FPGA Architecture delivering 2X the core performance gains
Up to 10 TFLOPS of single-precision floating-point DSP performance
Quad-core 64 bit ARM Cortex-A53 hard processor subsystem operating up to 1.5 GHz
Break Through the Bandwidth Barrier
Transceiver tiles (L-, H-, and E-tile) with data rates up to 56 Gbps that deliver 7X bandwidth vs. previous generation FPGAs
Dual-mode transceiver (E-tile) supports up to 56 Gbps PAM-4 and 30 Gbps NRZ
Up to 144 full duplex transceivers in a single package
Over 2.5 Tbps bandwidth for serial memory with support for Hybrid Memory Cube
Over 2.3 Tbps bandwidth for parallel memory interfaces with support for DDR4 at 2,666 Mbps
Lower Operating Expense
Leveraging Intel's leadership in process technology, Stratix 10 devices offer the most power-efficient technologies
Up to 70% lower power than prior-generation high-end FPGAs and SoCs
Up to 80 giga floating point operations per second (GFLOPS)/Watt of single-precision floating point power efficiency
Quad-core ARM Cortex-A53 processor optimized for performance per watt
Achieve the Highest Level of System Integration
Largest monolithic FPGA device with 5.5 million LEs
Heterogeneous 3D SiP solutions including transceivers and other advanced components
64 bit quad-core ARM Cortex-A53 to enable hardware virtualization, system management and monitoring capabilities, acceleration pre-processing, and



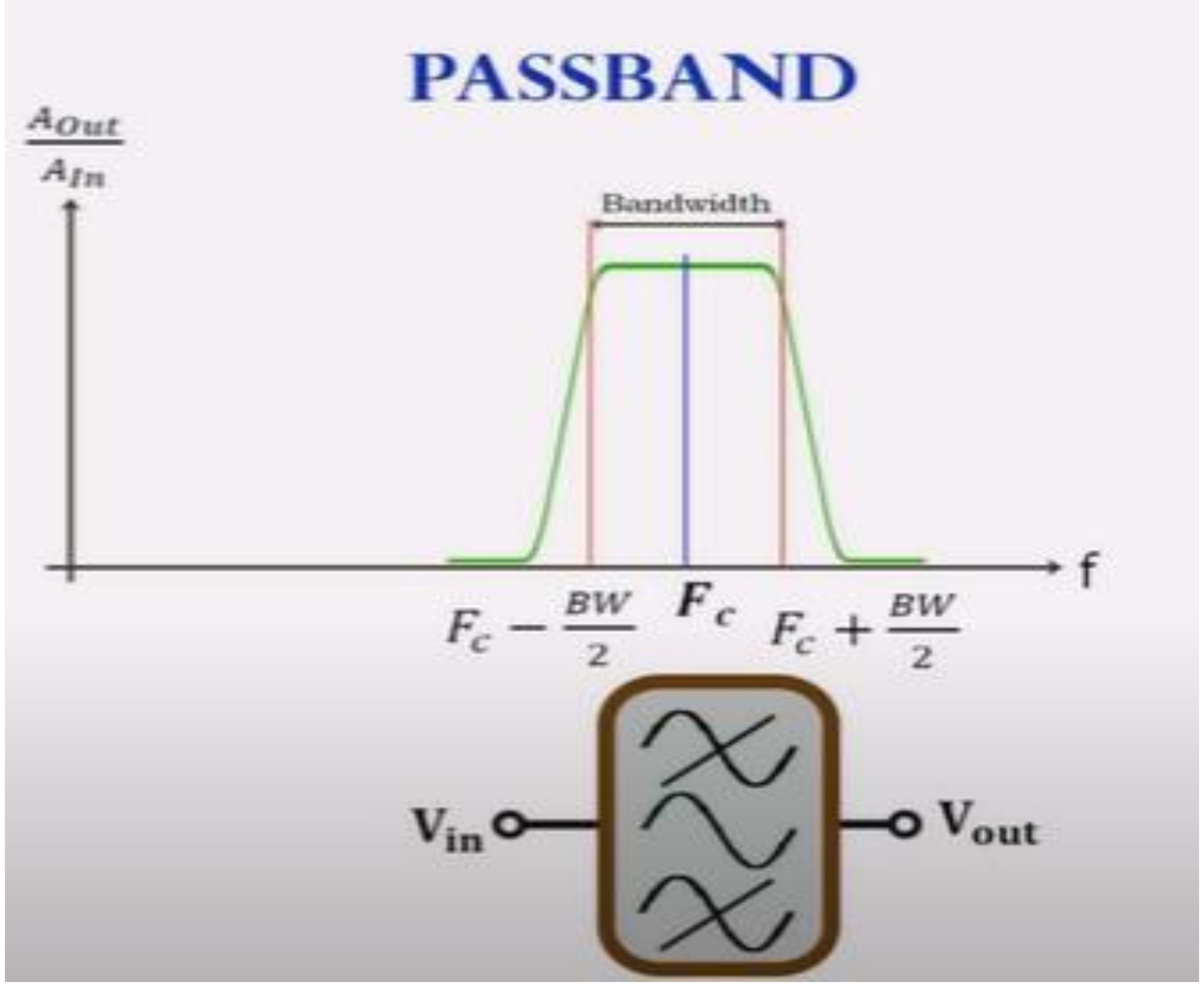
Analog Arts
Innovation Beyond Imagination
Home
Products
Downloads
The Company
Store
Learning Center
Selection Table
Search...
OSCILLOSCOPE FUNCTION GENERATOR
PC-Based Oscilloscope | SG985
Oscilloscope/ Spectrum Analyzer/ Data Recorder
2 channels
1 GHz analog input bandwidth
Rise time: 500 pS
1 nS to 365 days/division (data logger)
10-bit ADC
1 Megabyte data record length
SG Series Multi Instruments USB Oscilloscopes
10.0001064
Arbitrary Waveform Generator
10 mHz to 150 MHz output frequency
SG985 Video Description


BANDWIDTH
Relative Amplitude
Output amplitude
Input amplitude
Bandwidth = $F_H - F_L$ in Hertz
Bandwidth
F_L
F_H
Frequency (Hz)

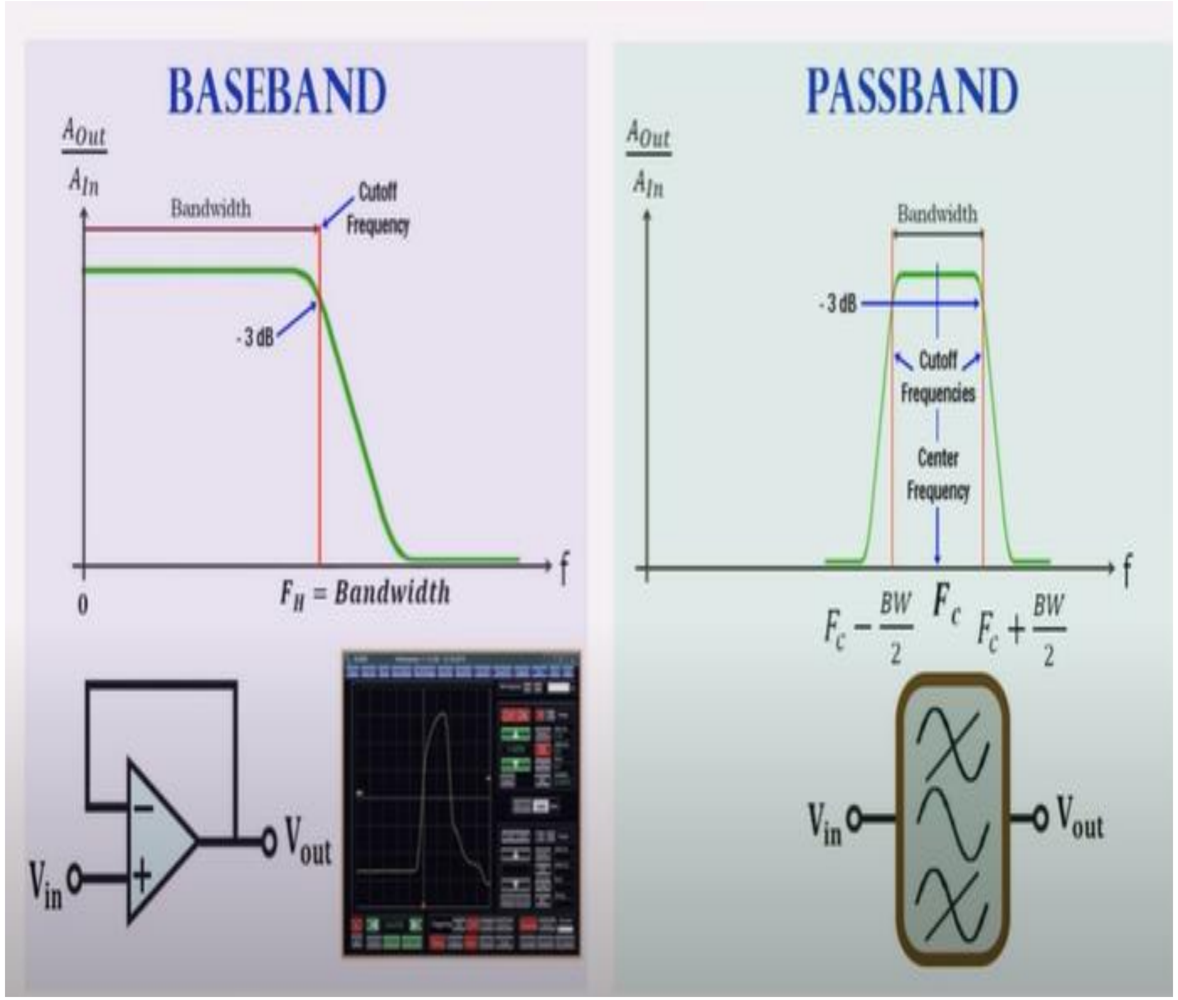

BANDWIDTH
Relative Amplitude
Output amplitude
Input amplitude
Bandwidth = $F_H - F_L$ in Hertz
0 dB
-3 dB
3 dB (29%)
Bandwidth
F_L
F_H
Frequency (Hz)



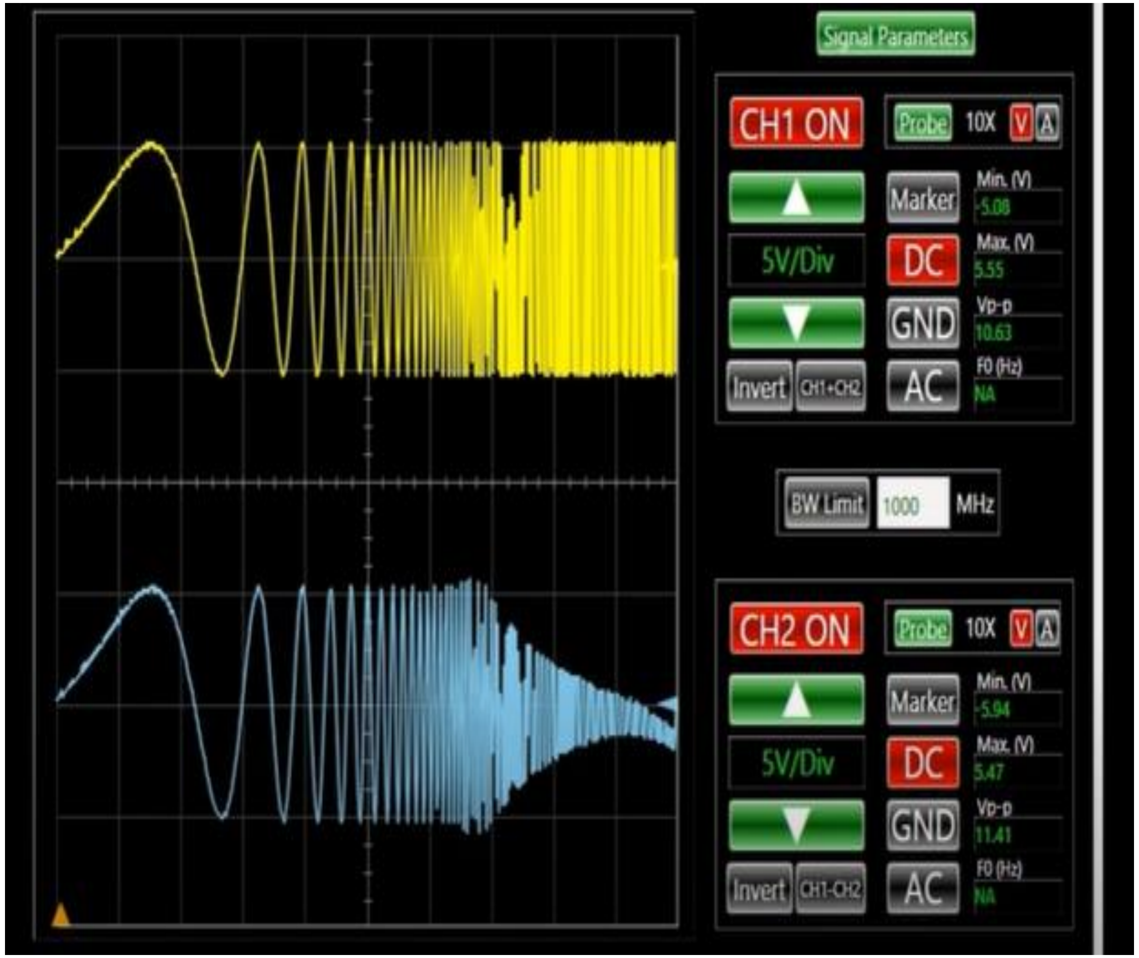
BASEBAND VS. PASSBAND
BASEBAND
$\frac{A_{Out}}{A_{In}}$
Bandwidth
f
0
F_H = Bandwidth
V_{in}
V_{out}



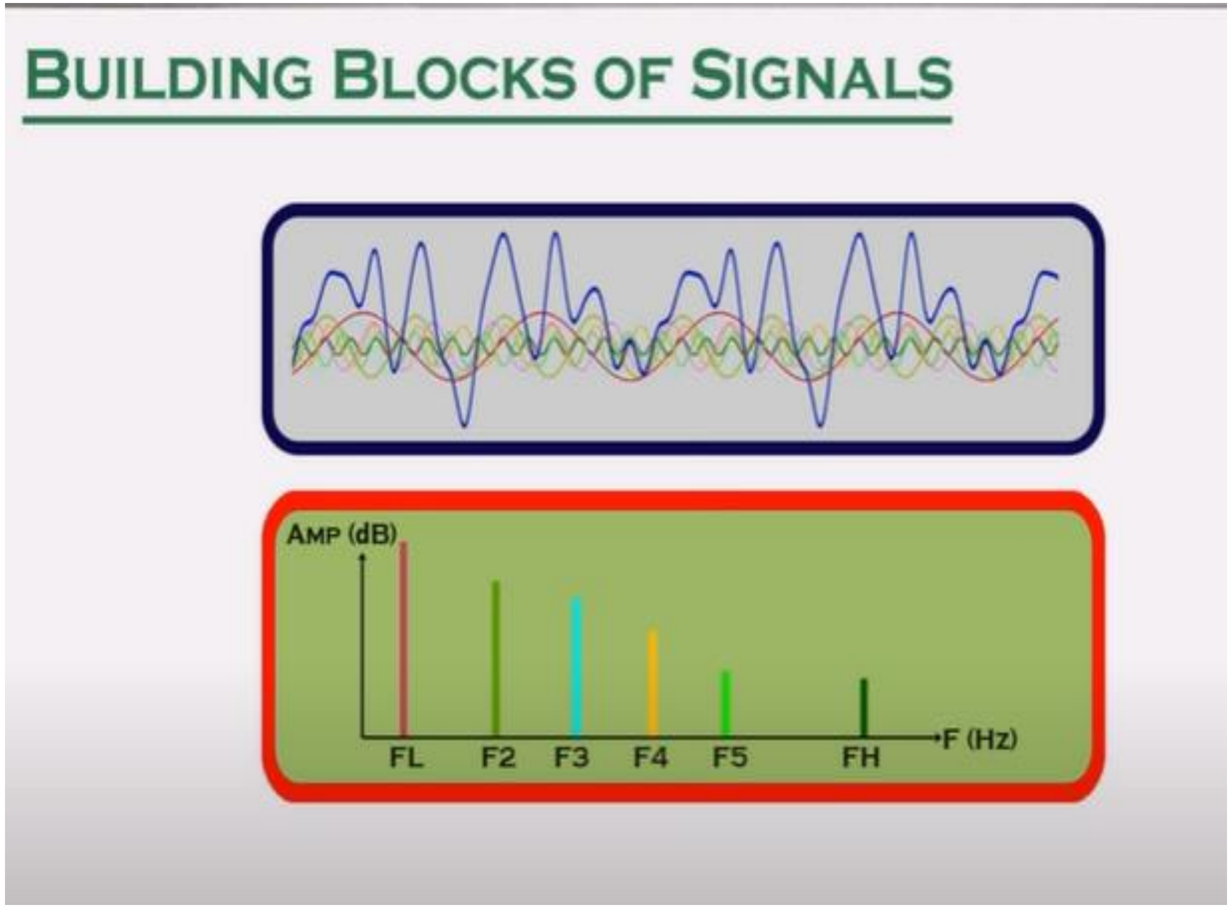
PASSBAND
$\frac{A_{Out}}{A_{In}}$
Bandwidth
f
$F_c - \frac{BW}{2}$
F_c
$F_c + \frac{BW}{2}$
V_{in}
V_{out}

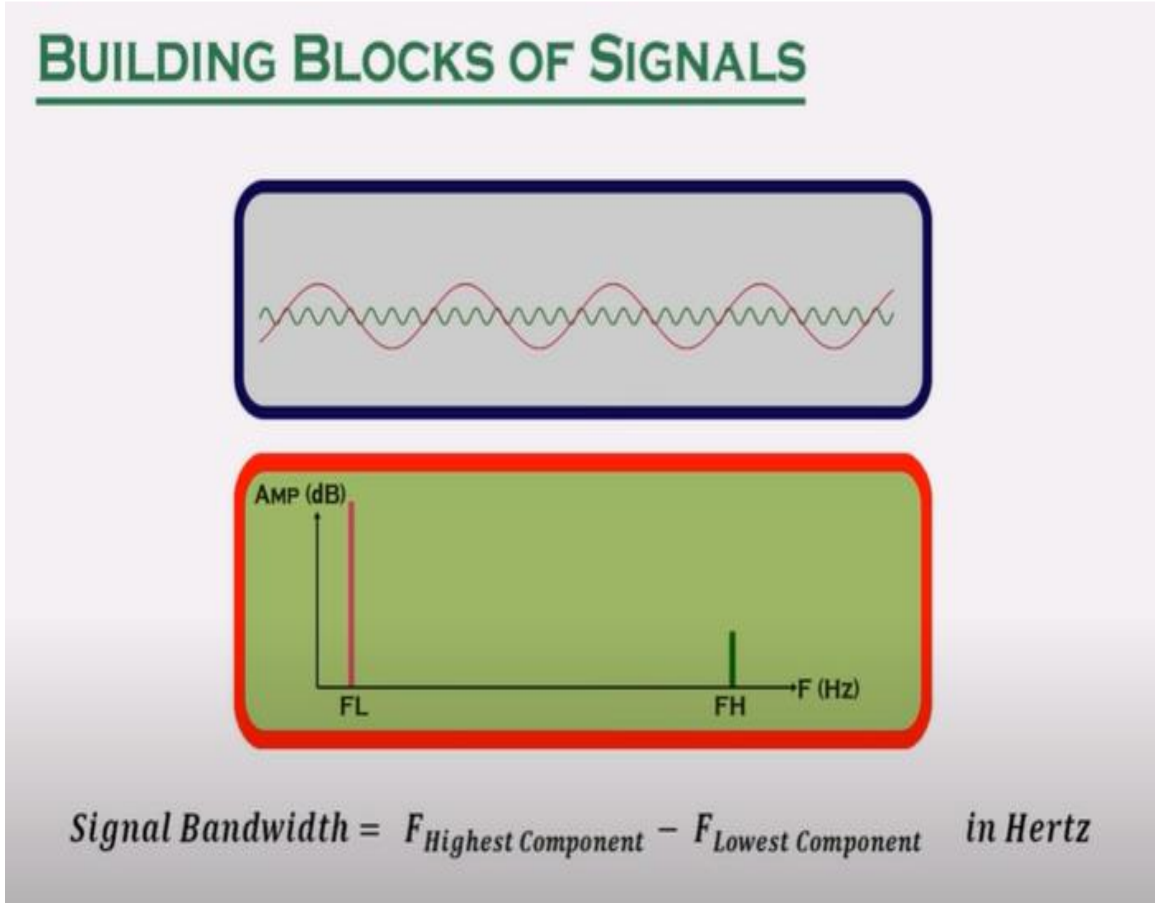


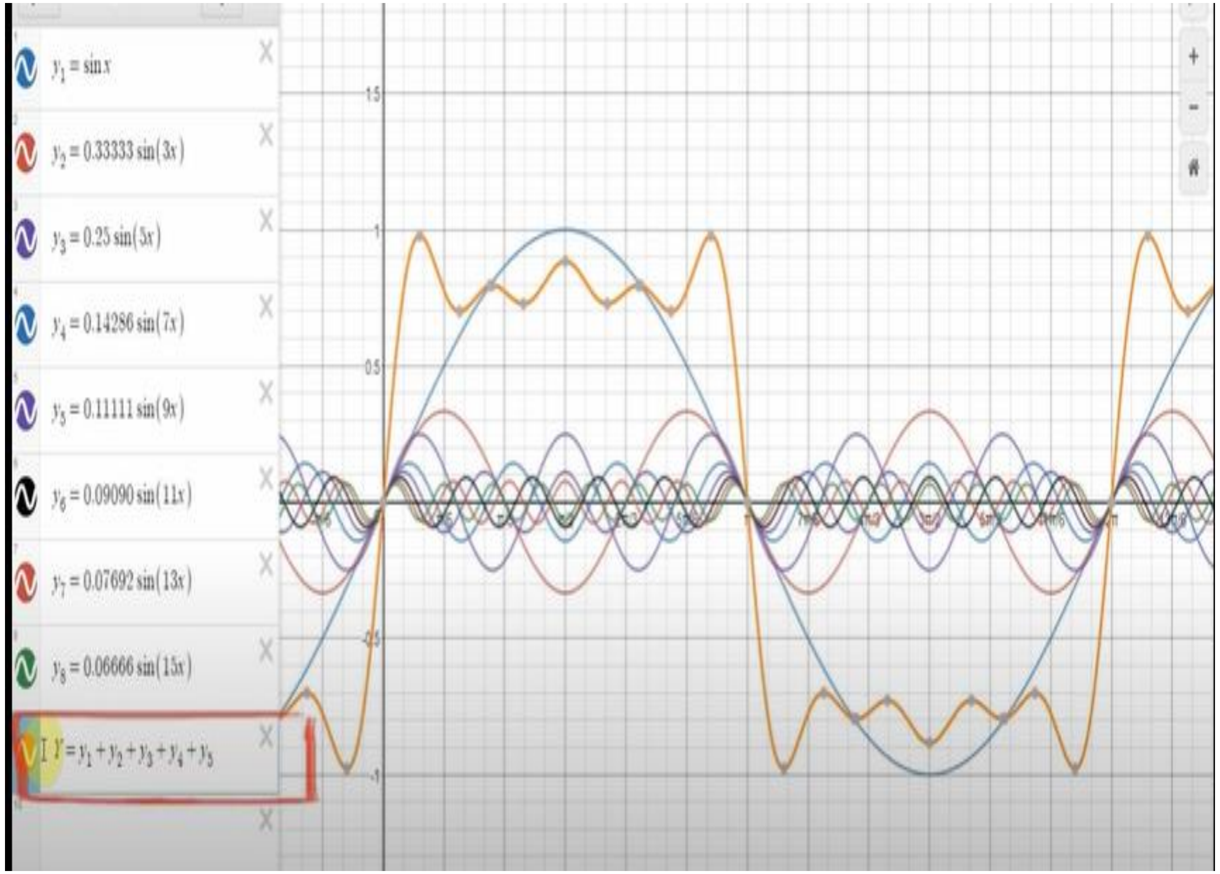
BASEBAND
$\frac{A_{Out}}{A_{In}}$
Bandwidth
Cutoff Frequency
-3 dB
0
f
$F_H = Bandwidth$
V_{in}
V_{out}
PASSBAND
$\frac{A_{Out}}{A_{In}}$
Bandwidth
-3 dB
Cutoff Frequencies
Center Frequency
f
$F_c - \frac{BW}{2}$
F_c
$F_c + \frac{BW}{2}$
V_{in}
V_{out}



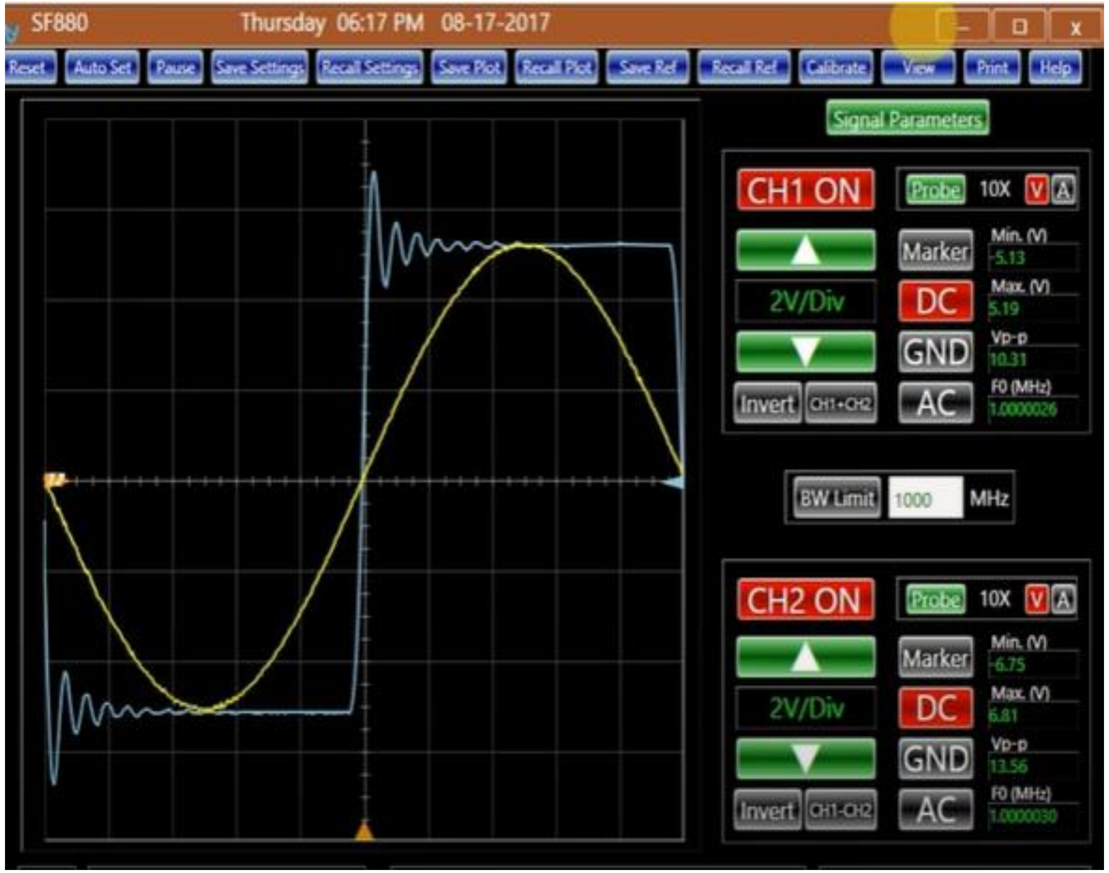
Signal Parameters
CH1 ON
Probe
10X
V
A
Marker
Min. (V)
-5.08
5V/Div
DC
Max. (V)
5.55
GND
Vp-p
10.63
Invert
CH1+CH2
AC
F0 (Hz)
NA
BW Limit
1000
MHz
CH2 ON
Probe
10X
V
A
Marker
Min. (V)
-5.94
5V/Div
DC
Max. (V)
5.47
GND
Vp-p
11.41
Invert
CH1-CH2
AC
F0 (Hz)
NA


BUILDING BLOCKS OF SIGNALS
AMP (dB)
FL
F2
F3
F4
F5
FH
F (Hz)

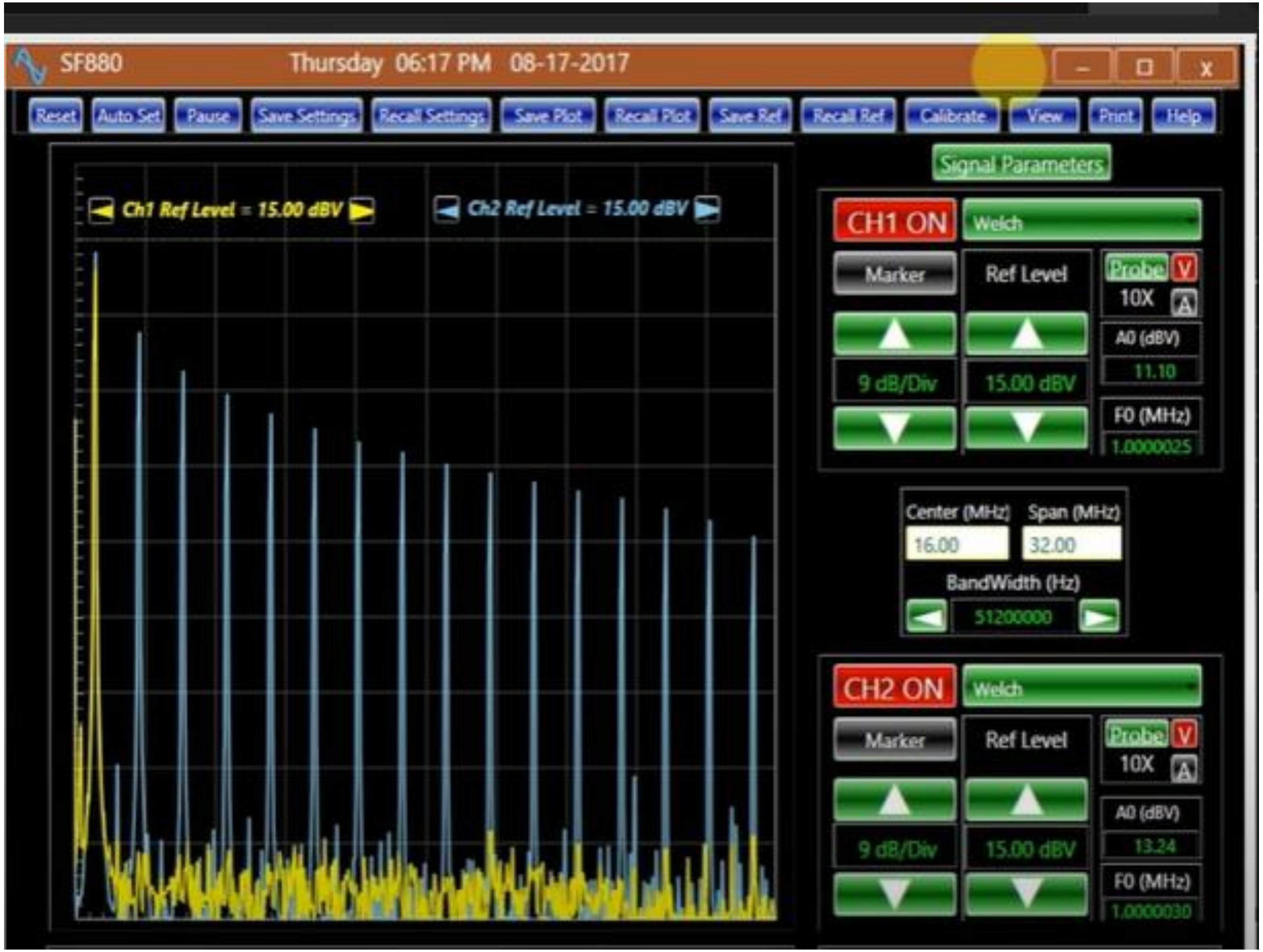

BUILDING BLOCKS OF SIGNALS
AMP (dB)
FL
FH
F (Hz)
Signal Bandwidth = $F_{Highest\ Component} - F_{Lowest\ Component}$ in Hertz



y1 = sin x
y2 = 0.33333 sin(3x)
y3 = 0.25 sin(5x)
y4 = 0.14286 sin(7x)
y5 = 0.11111 sin(9x)
y6 = 0.09090 sin(11x)
y7 = 0.07692 sin(13x)
y8 = 0.06666 sin(15x)
Y = y1 + y2 + y3 + y4 + y5
1.5
1
0.5
-1



SF880
Thursday 06:17 PM 08-17-2017
Reset
Auto Set
Pause
Save Settings
Recall Settings
Save Plot
Recall Plot
Save Ref
Recall Ref
Calibrate
View
Print
Help
Signal Parameters
CH1 ON
Probe
10X
V
A
Marker
Min. (V)
-5.13
2V/Div
DC
Max. (V)
5.19
GND
Vp-p
10.31
Invert
CH1+CH2
AC
F0 (MHz)
1.0000026
BW Limit
1000
MHz
CH2 ON
Probe
10X
V
A
Marker
Min. (V)
-6.75
2V/Div
DC
Max. (V)
6.81
GND
Vp-p
13.56
Invert
CH1-CH2
AC
F0 (MHz)
1.0000030


SF880
Thursday 06:17 PM 08-17-2017
Reset
Auto Set
Pause
Save Settings
Recall Settings
Save Plot
Recall Plot
Save Ref
Recall Ref
Calibrate
View
Print
Help
Signal Parameters
Ch1 Ref Level = 15.00 dBV
Ch2 Ref Level = 15.00 dBV
CH1 ON
Welch
Marker
Ref Level
Probe
V
10X
A
A0 (dBV)
11.10
9 dB/Div
15.00 dBV
F0 (MHz)
1.0000025
Center (MHz)
Span (MHz)
16.00
32.00
BandWidth (Hz)
51200000
CH2 ON
Welch
Marker
Ref Level
Probe
V
10X
A
A0 (dBV)
13.24
9 dB/Div
15.00 dBV
F0 (MHz)
1.0000030

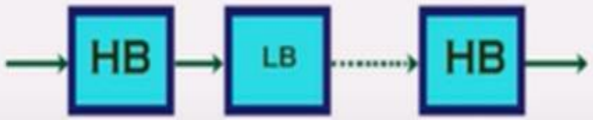
BANDWIDTH REQUIREMENT

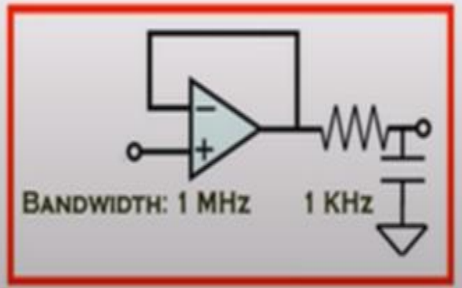
System Bandwidth >> Signal's Highest Frequency Component

Signal Bandwidth $= 2\ MHz$,

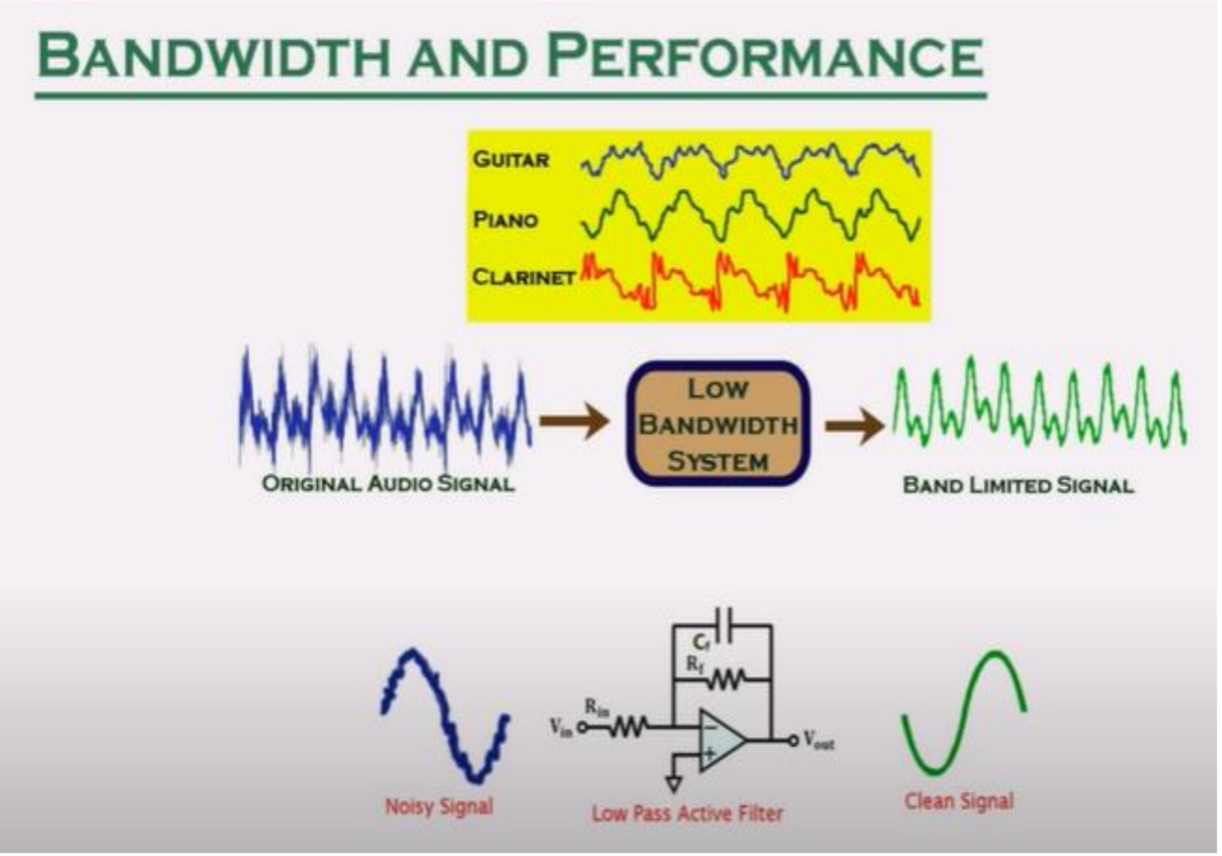
Center Frequency $= 10\ MHz$

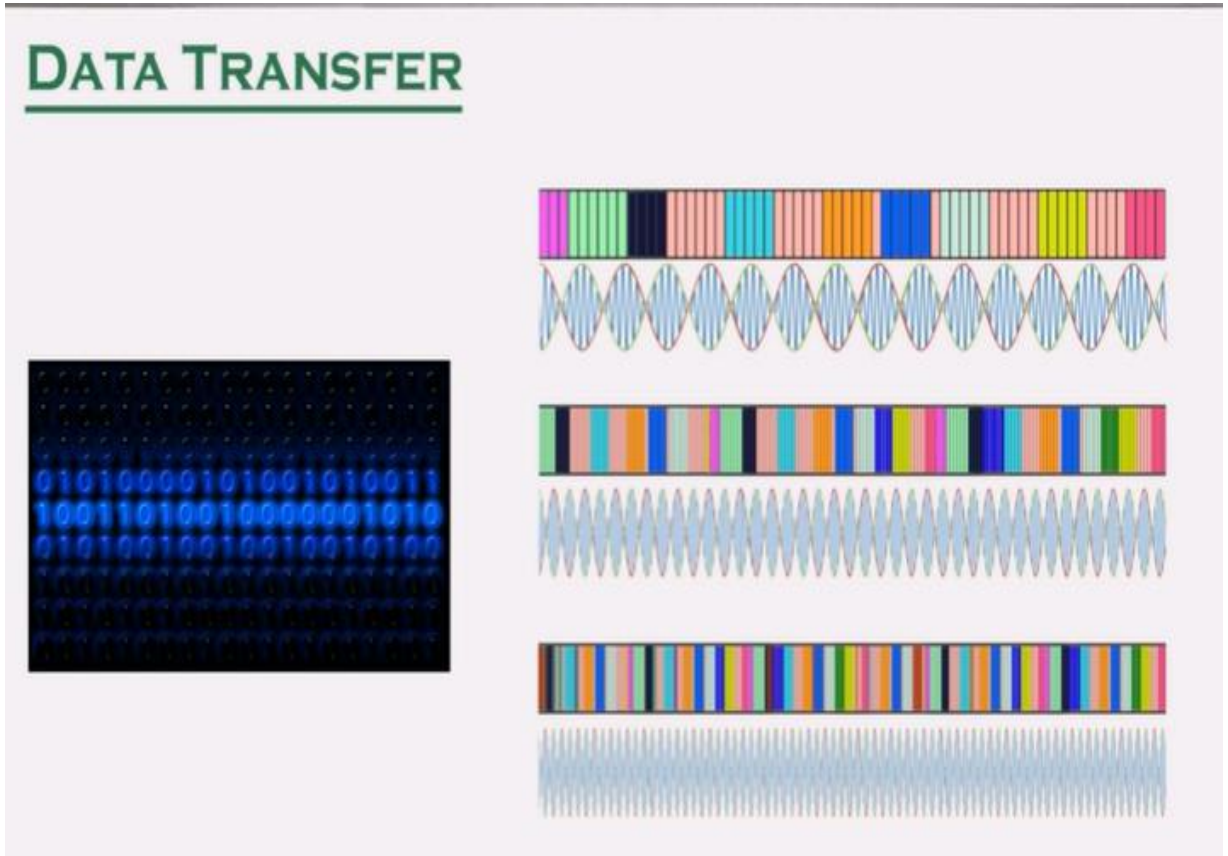
System Bandwidth $\gg 11\ MHz\ (10\ MHz + \frac{2\ MHz}{2})$





Circuit Bandwidth $\simeq 1\ KHz$


BANDWIDTH AND PERFORMANCE
GUITAR
PIANO
CLARINET
ORIGINAL AUDIO SIGNAL
LOW BANDWIDTH SYSTEM
BAND LIMITED SIGNAL
C_f
R_f
R_{in}
V_{in}
V_{out}
Noisy Signal
Low Pass Active Filter
Clean Signal

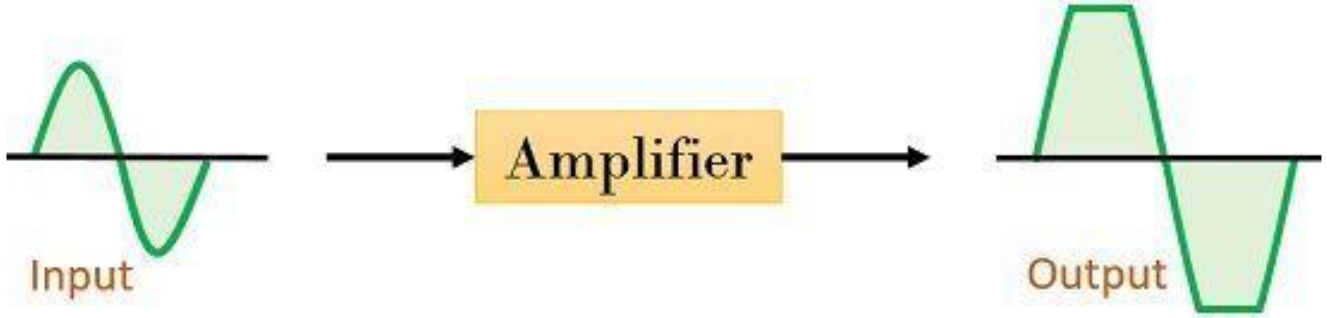

DATA TRANSFER

Distortion in Amplifier

Distortion in Amplifier basically implies the **variation in the waveform received at the output** with respect to the applied input.The unwanted alterations generated during amplification is known as distortion.

A pure signal always has a single frequency component where voltage varies positive and negative by an equal amount. If this variation is less than full 360º cycle, then it is said that the signal is **distorted.**

When we talk about an ideal amplifier, the amplified output must be an exact replica of the input. But practically such an ideal amplifier doesn’t exist. These undesired changes in the signal at the amplifier’s output are basiaclly termed as distortion in amplifier.



Distorted Output Of an Amplifier

For a distortionless output signal, dc biasing is required at the base or gate terminal. When dc biasing is employed, the signal is amplified over its entire cycle. The bias **“Q point”** must fall at the middle of the load line.

Thus, with such a “Q point” setting, type A amplification can be achieved. To have a detailed explanation about class A amplifiers refer to our previous article Power Amplifier.

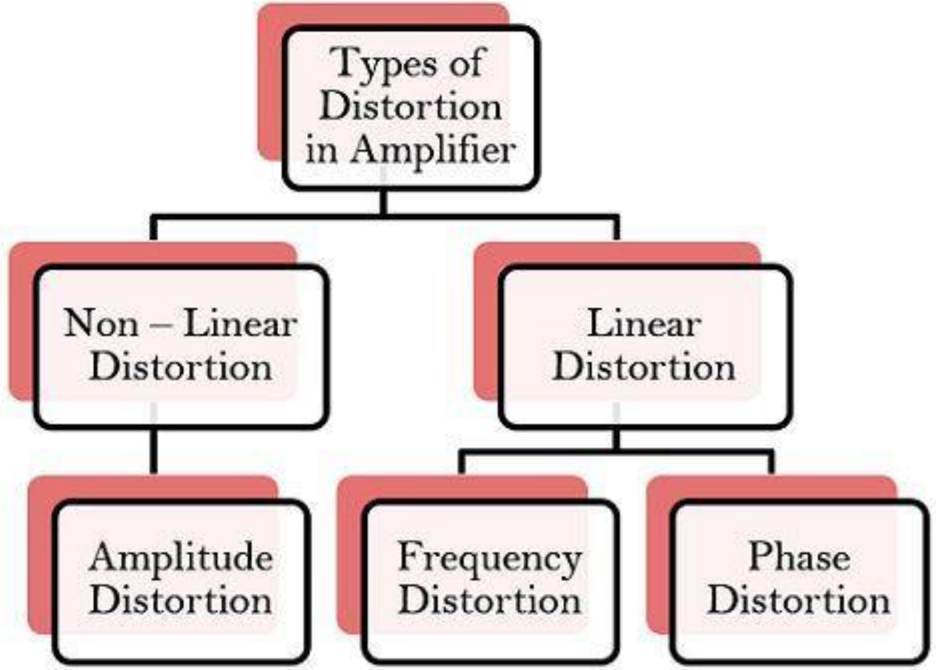
Reasons for signal distortion–

1.Due to incorrect biasing when the signal is not amplified for the entire cycle of the input signal then distortion occurs.
2.It also occurs in the case when the applied input signal is very large.
3.Distortion in amplifier sometimes results when the amplification is not linear over the complete frequency range.

the amplifiers basically **amplify small voltage signals** in order to **provide a larger signal at the output**. After amplification, the output signal is the value obtained by the multiplication of amplifier's gain with that of the input signal.

This is the reason why we get an amplified signal at the output of an amplifier. But the gain of amplifier i.e., β is different for the even similar type of transistor. Thus causing variation of "Q point" from a transistor to other

Types of Distortion in Amplifier

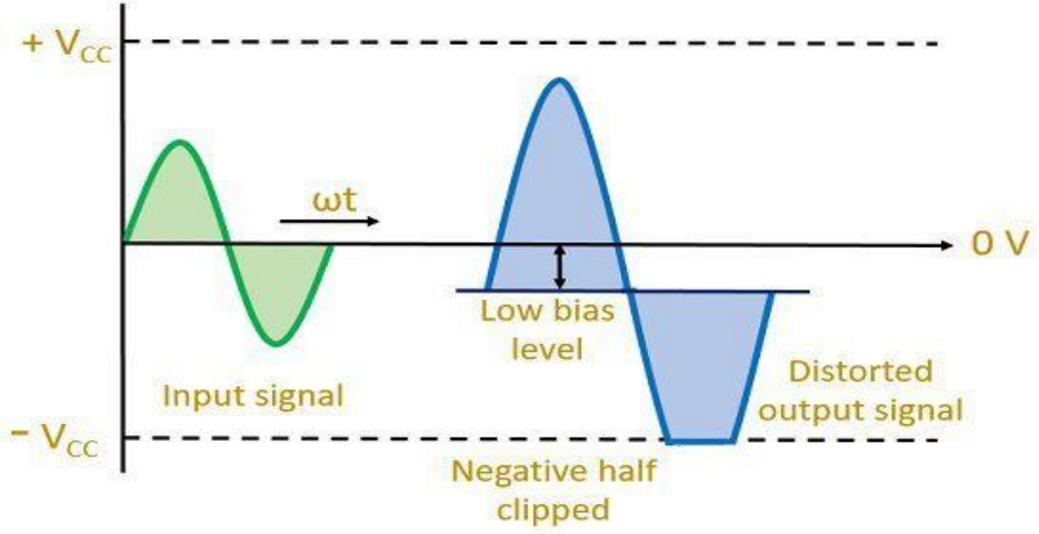


Non-linear Distortion – This type of distortion occurs in an amplifier when the signal input is large and the active device is driven into a non-linear region of its characteristics.

Amplitude Distortion:

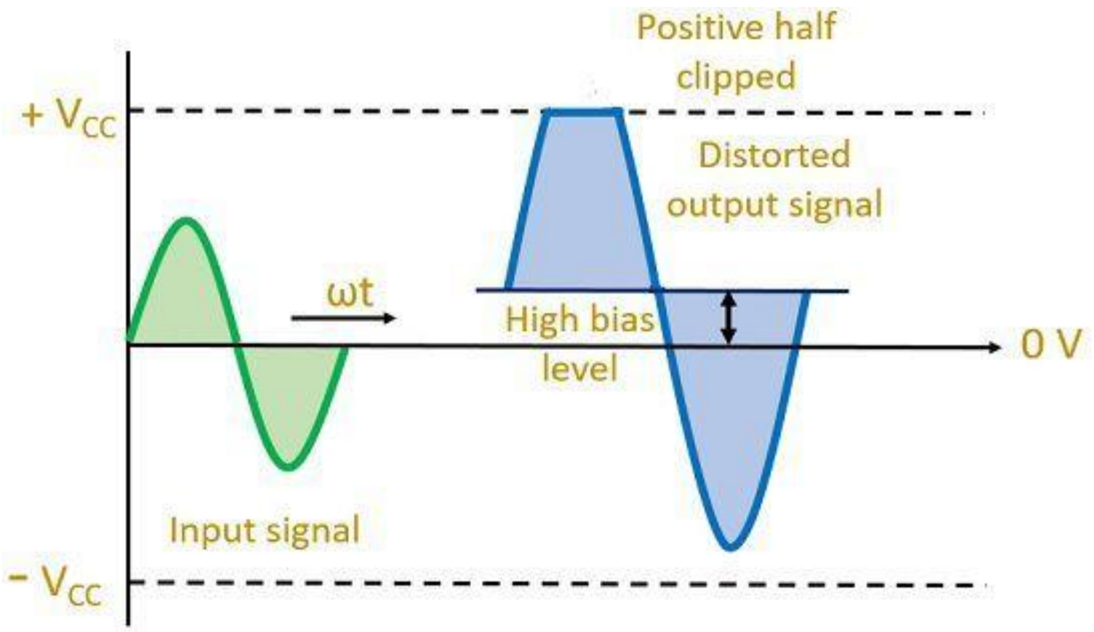
This type of distortion occurs due to attenuation in the peak value of the waveform. **The shift in "Q point" and amplification for less than 360^0 of the input signal leads to amplitude distortion**. It occurs mainly due to **incorrect biasing and clipping**. As we know that if the biasing point of the transistor is correct, one can have output is the exact replica of input in the amplified form. Let us understand it with the help of the following three cases –

Case 1: Suppose insufficient biasing is provided, the "Q point" will lie near the lower half of the load line. In such condition, negative half of input is clipped and we get a distorted signal at the output of the amplifier.



The condition of Distortion at a low bias level

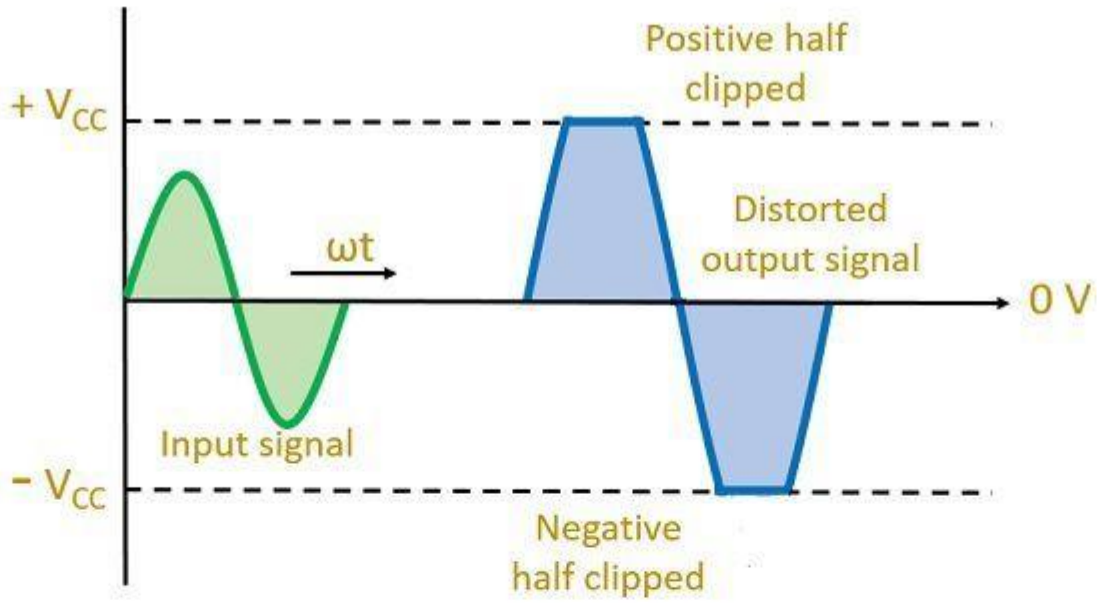
Case 2: Suppose an extra bias potential is provided, the “Q point” will now be at the upper half of the load line. This condition gives an output that is cut-off at positive half of the waveform.



The condition of Distortion at a high bias level

Case 3: Sometimes correct biasing also leads to distortion in the output in case of the large input signal. This is so because the large input signal is amplified by the gain of the amplifier. In this case, both positive and negative half of the waveform gets clipped at some portion.

This is also known as clipping distortion. The efficiency of the circuit extremely decreases due to amplitude distortion

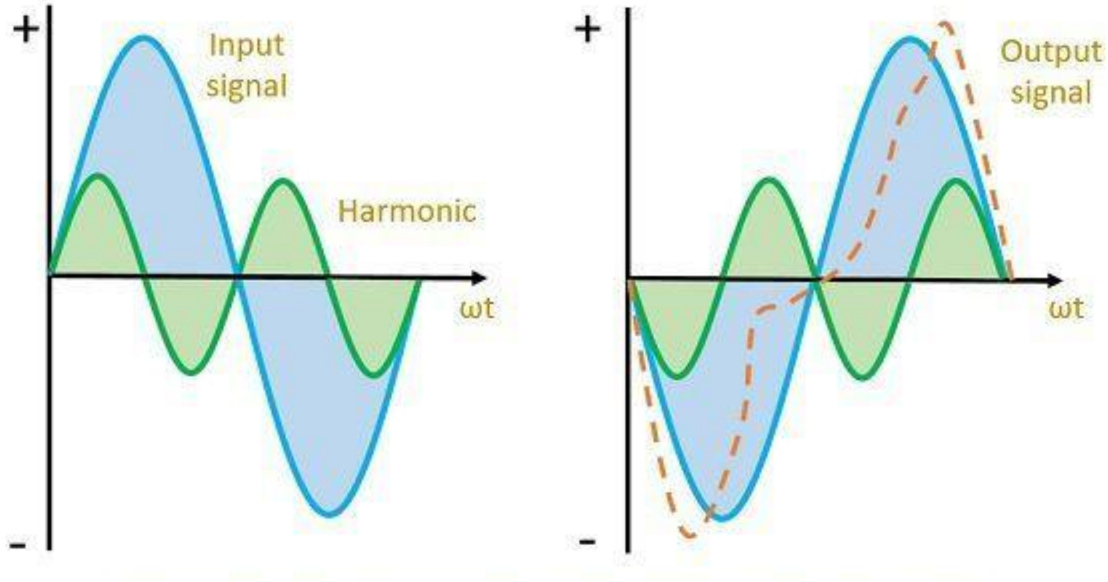


Distortion due to large input signal

Linear Distortion – This type of distortion occurs when small input signal drives the device and it operates in the linear region of its characteristics. This mainly occurs due to frequency dependent characteristics of the active devices.

Frequency Distortion:

In frequency distortion, the level of amplification varies with respect to frequency. In a practical amplifier, during amplification input signal consist of fundamental frequency along with different frequency components. This different frequency component is known as harmonics. After amplification, the amplitude of harmonics is somewhat a fraction of fundamental amplitude. Resultantly causing no any severe effect at the output waveform. But if the amplitude of harmonics after amplification goes to a higher value then its effect can't be avoided as it will be noticeable at the output. The diagram shown below will help you to understand frequency distortion clearly-

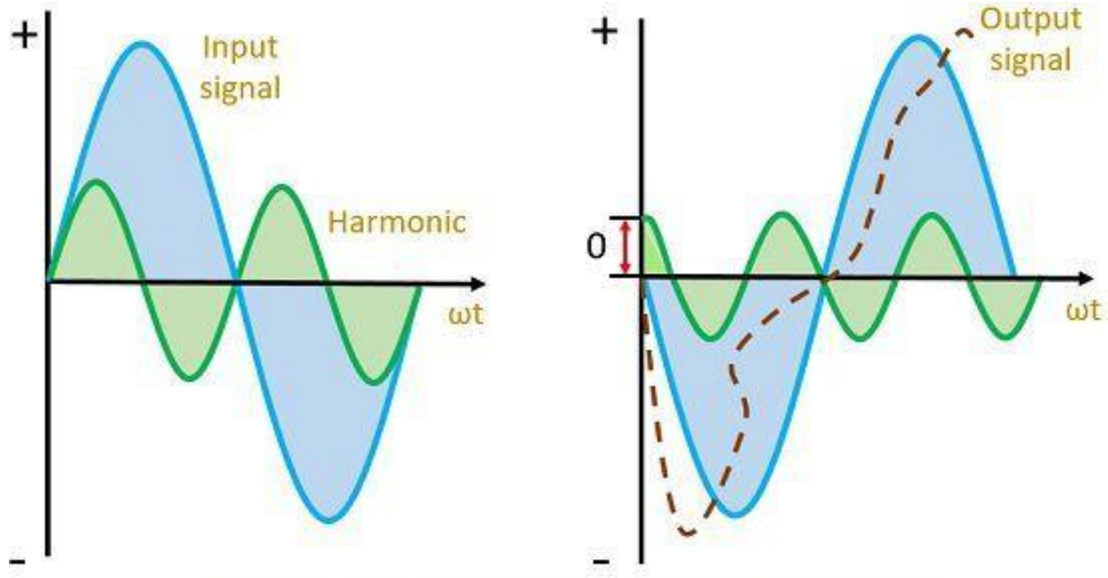


Frequency Distortion due to Harmonics

Here the input consists of fundamental frequency along with harmonics. The combination of the two on amplification will give a distorted signal at the output. It occurs either due to the presence of reactive elements or by the electrode capacitances of the amplifier circuits.

Phase Distortion:

Phase Distortion in the amplifier is also known as delay distortion. As the name indicates whenever there is a time delay between input and occurrence of the signal at the output. It is said to be phase distorted signal. It occurs mainly due to electrical reactance. As we have discussed that a signal consists of different frequency components. So, when different frequency suffers different phase shift, phase distortion takes place.



Phase Distortion due to delay

Phase distortion has no practical significance in audio amplifiers as the human ear is insensitive to phase shift. The type and amount of distortion that is tolerable or intolerable depend on the application of amplifier.