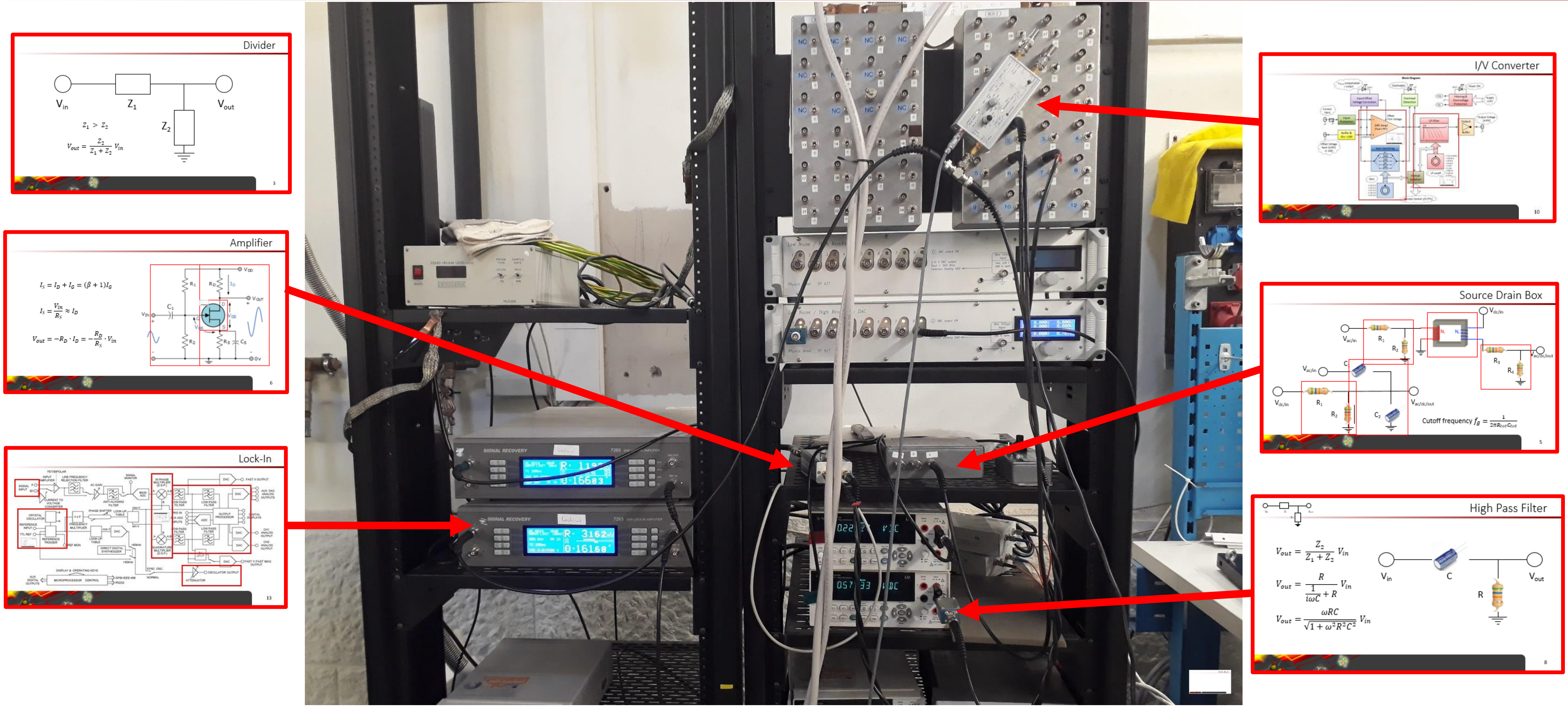
Labtutorial

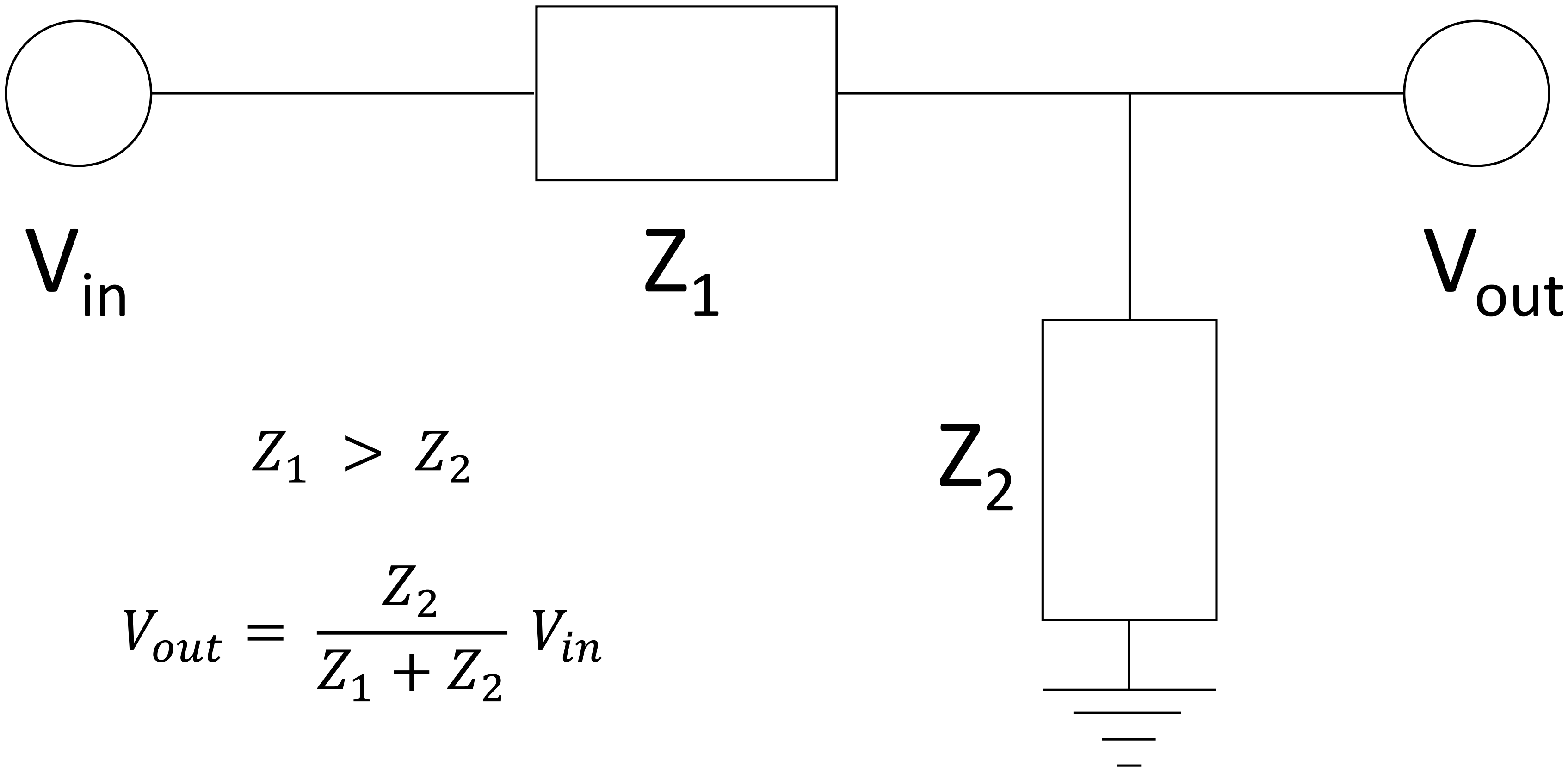
Electronic Circuits, I/V Converter and Lock-in

Timothy Camenzind

03.05.2019

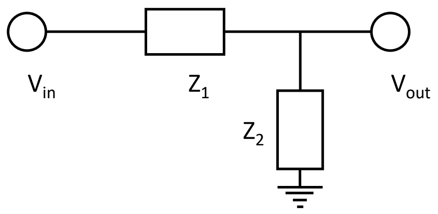
Typical Measurement Setup

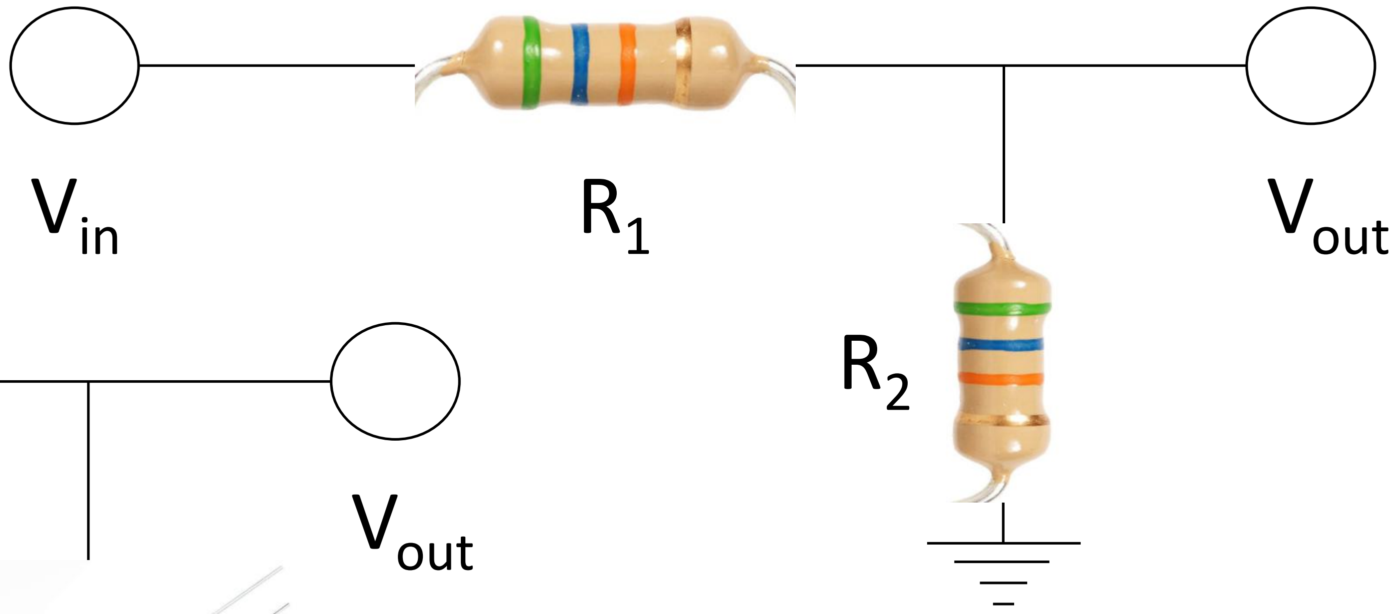


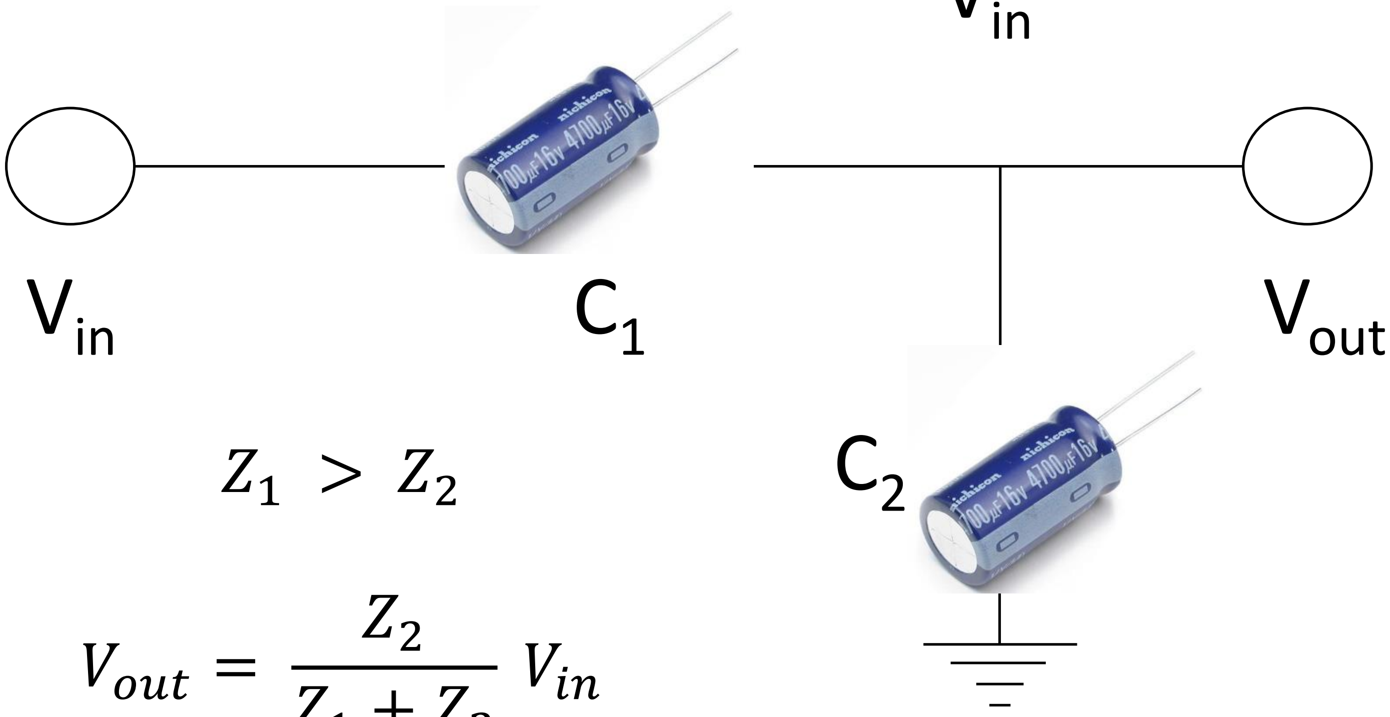


$$Z_1 \; > \; Z_2$$

$$V_{out} = \frac{Z_2}{Z_1 + Z_2} V_{in}$$



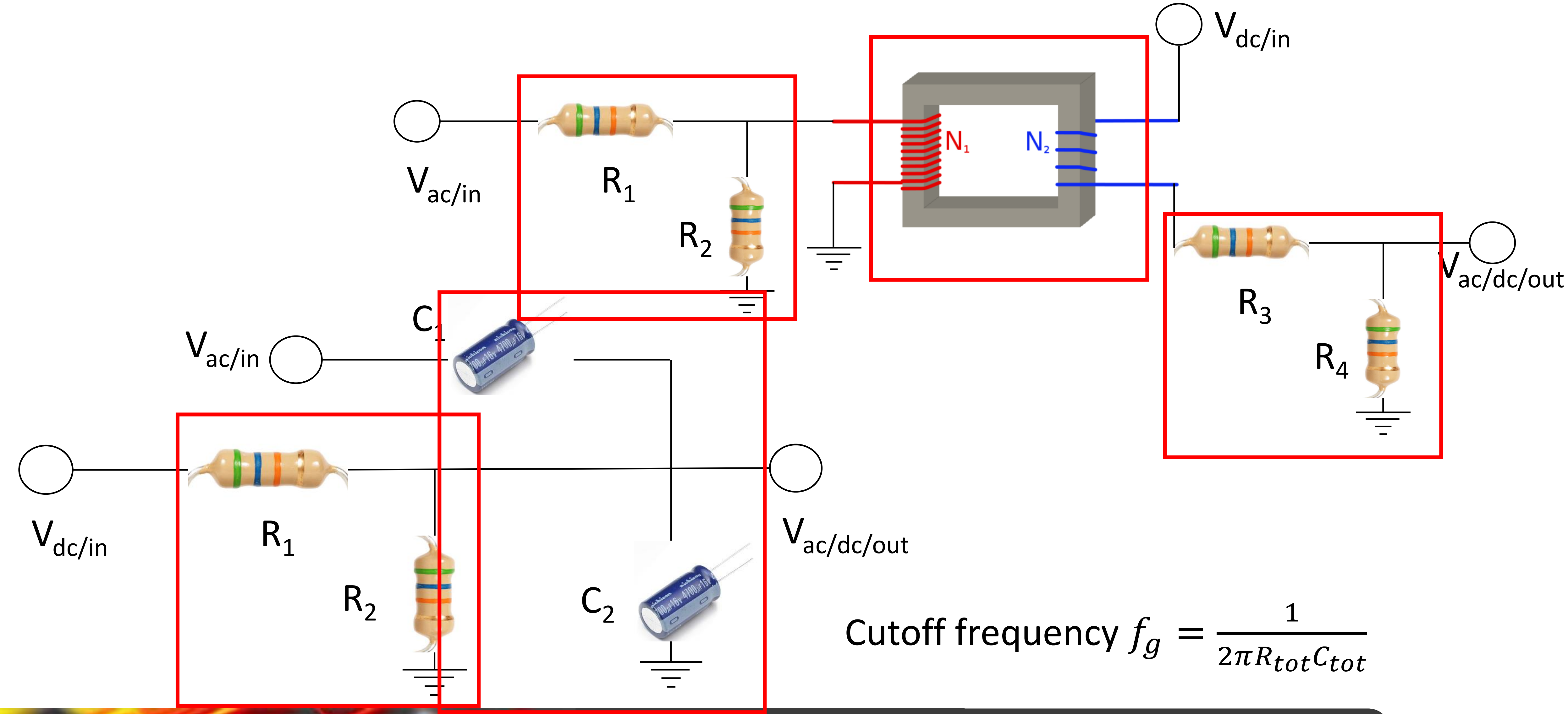




$$Z_1 > Z_2$$

$$V_{out} = \frac{Z_2}{Z_1 + Z_2} V_{in}$$

Source Drain Box



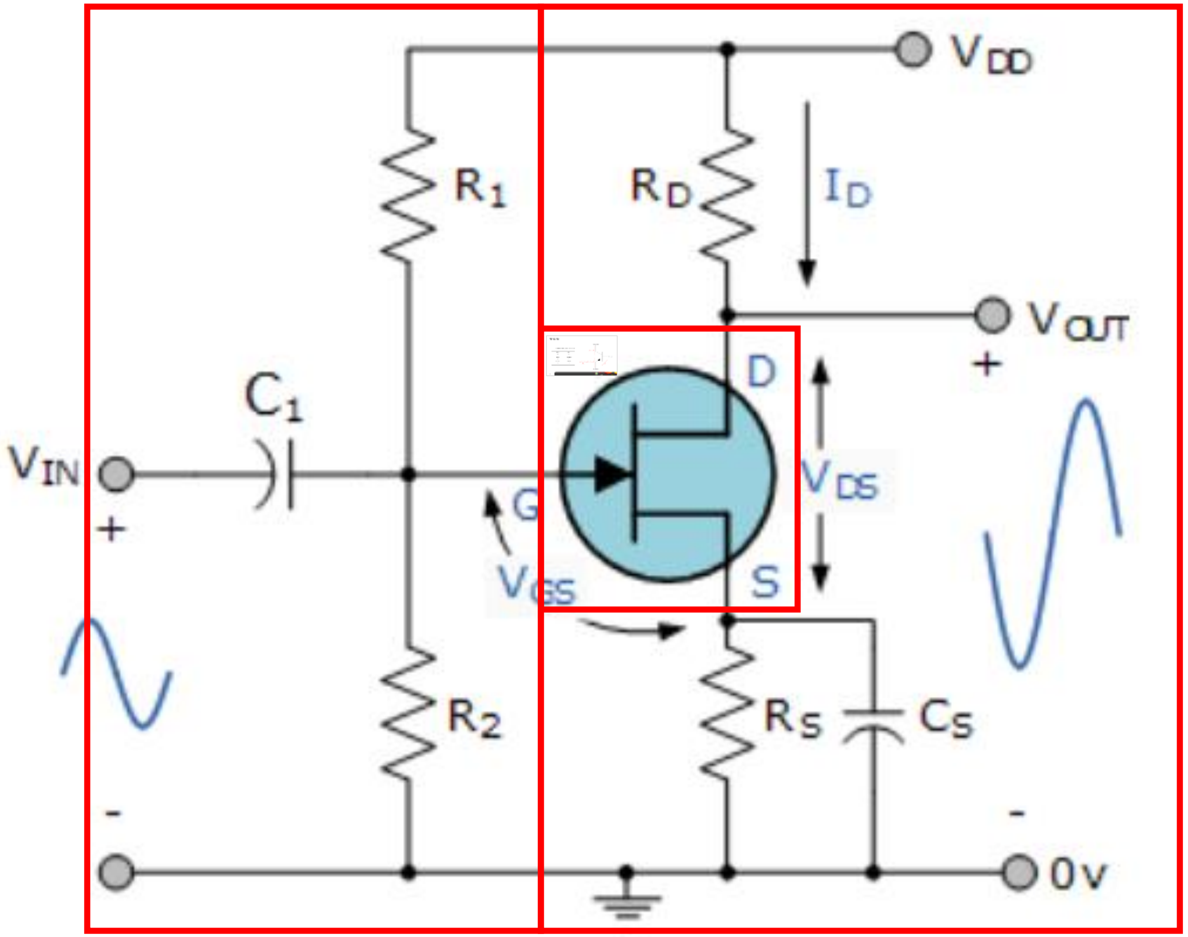
Cutoff frequency $f_g = \frac{1}{2\pi R_{tot} C_{tot}}$

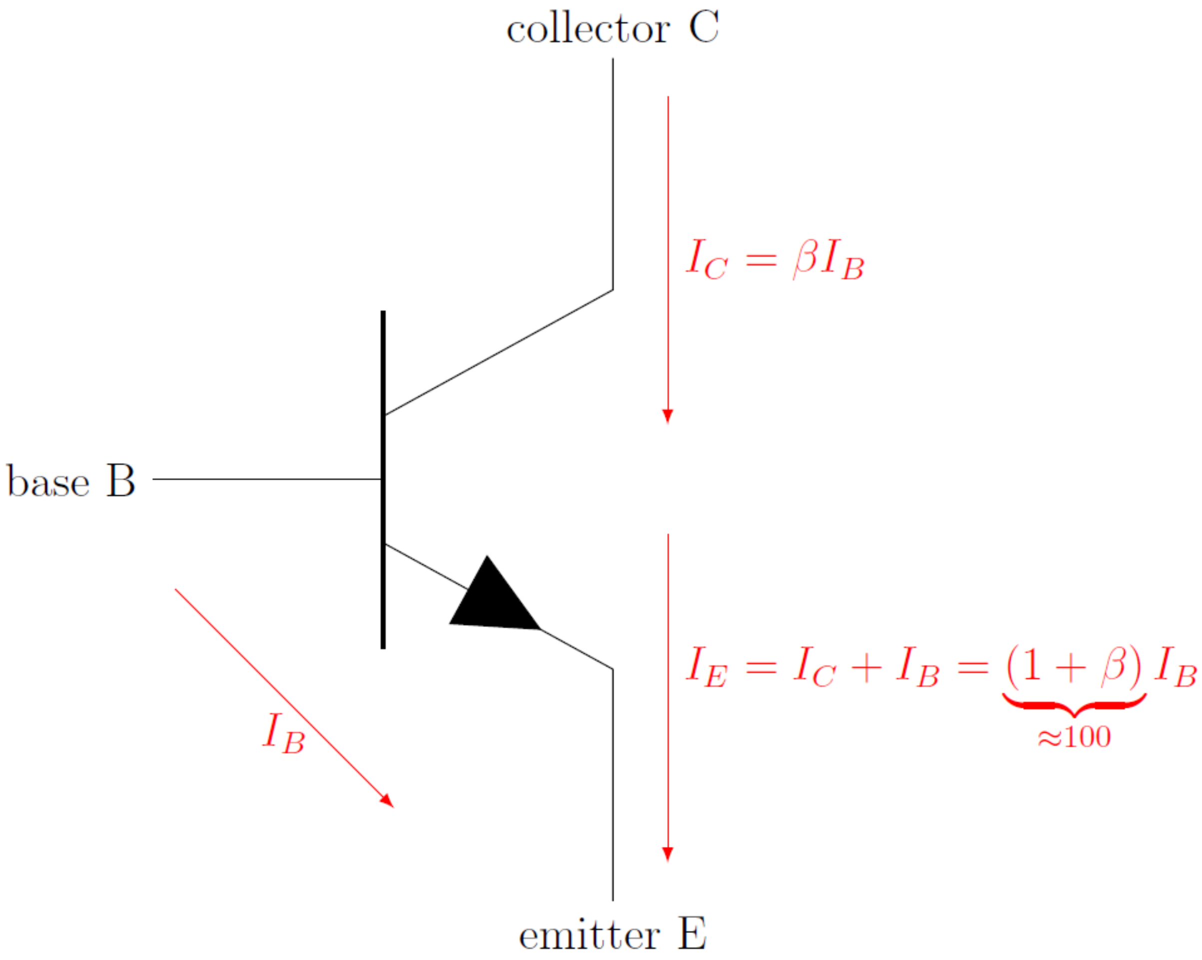
Amplifier

$$I_S = I_D + I_G = (\beta + 1) I_G$$

$$I_S = \frac{V_{in}}{R_S} \approx I_D$$

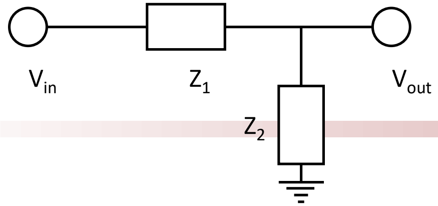
$$V_{out} = -R_D \cdot I_D = -\frac{R_D}{R_S} \cdot V_{in}$$





Equivalents in FETs, JFETs, MOSFETs

Base B	Gate G
Collector C	Drain D
Emitter E	Source S

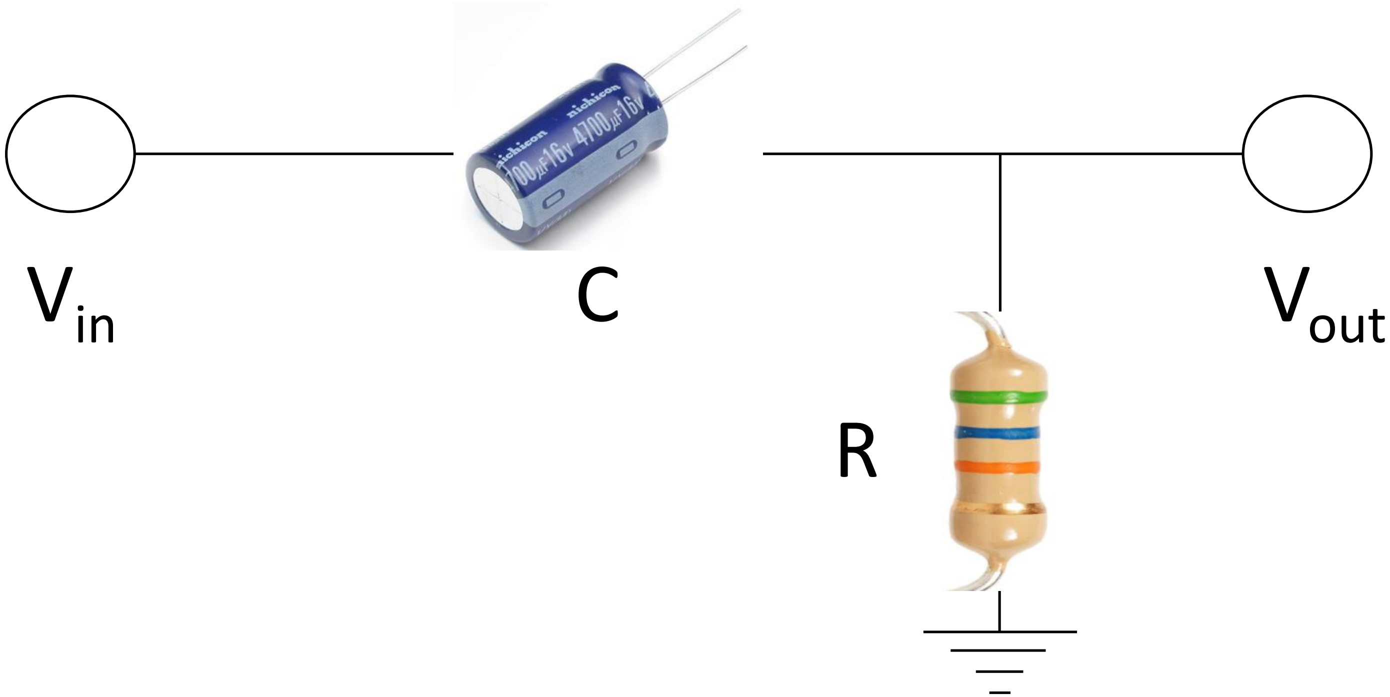


High Pass Filter

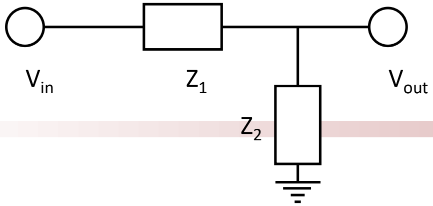
$$V_{out} = \frac{Z_2}{Z_1 + Z_2} V_{in}$$

$$V_{out} = \frac{R}{\frac{1}{i\omega C} + R} V_{in}$$

$$V_{out} = \frac{\omega RC}{\sqrt{1 + \omega^2 R^2 C^2}} V_{in}$$



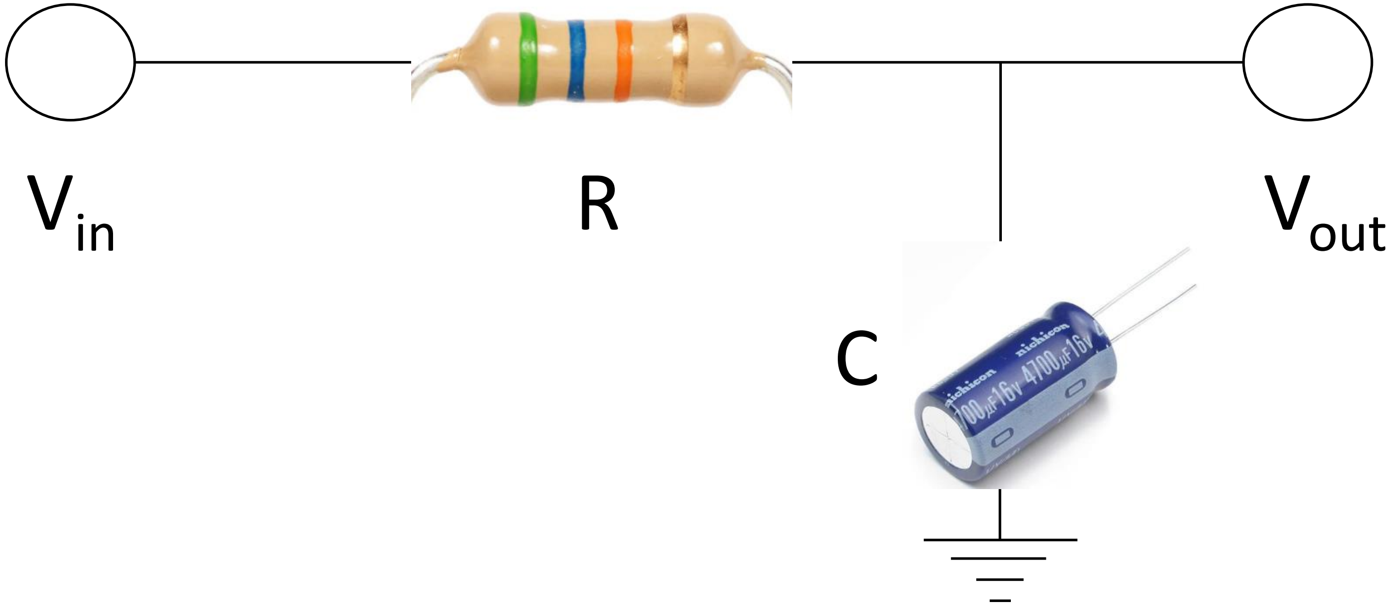
Low Pass Filter



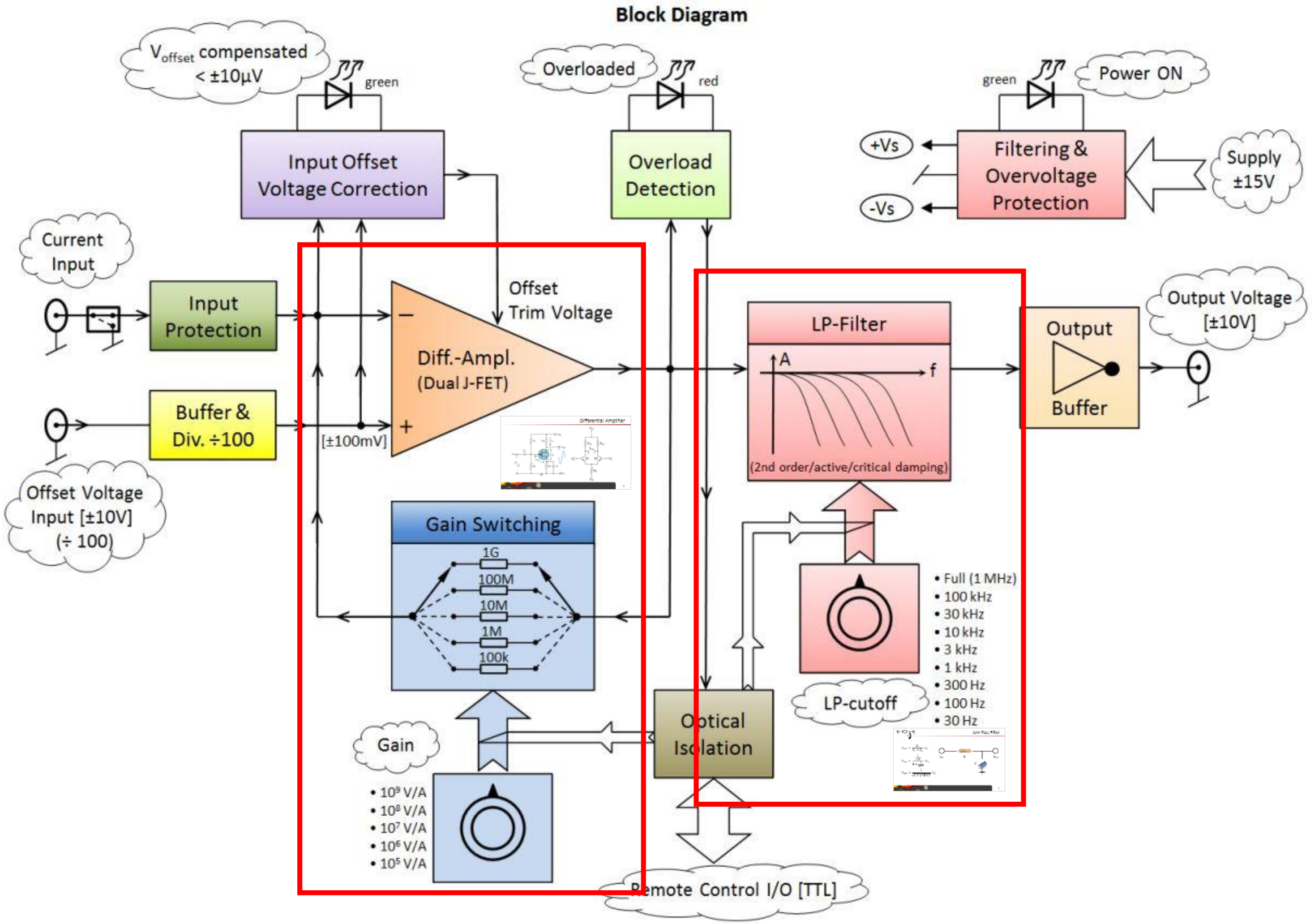
$$V_{out} = \frac{Z_2}{Z_1 + Z_2} V_{in}$$

$$V_{out} = \frac{\frac{1}{i\omega C}}{R + \frac{1}{i\omega C}} V_{in}$$

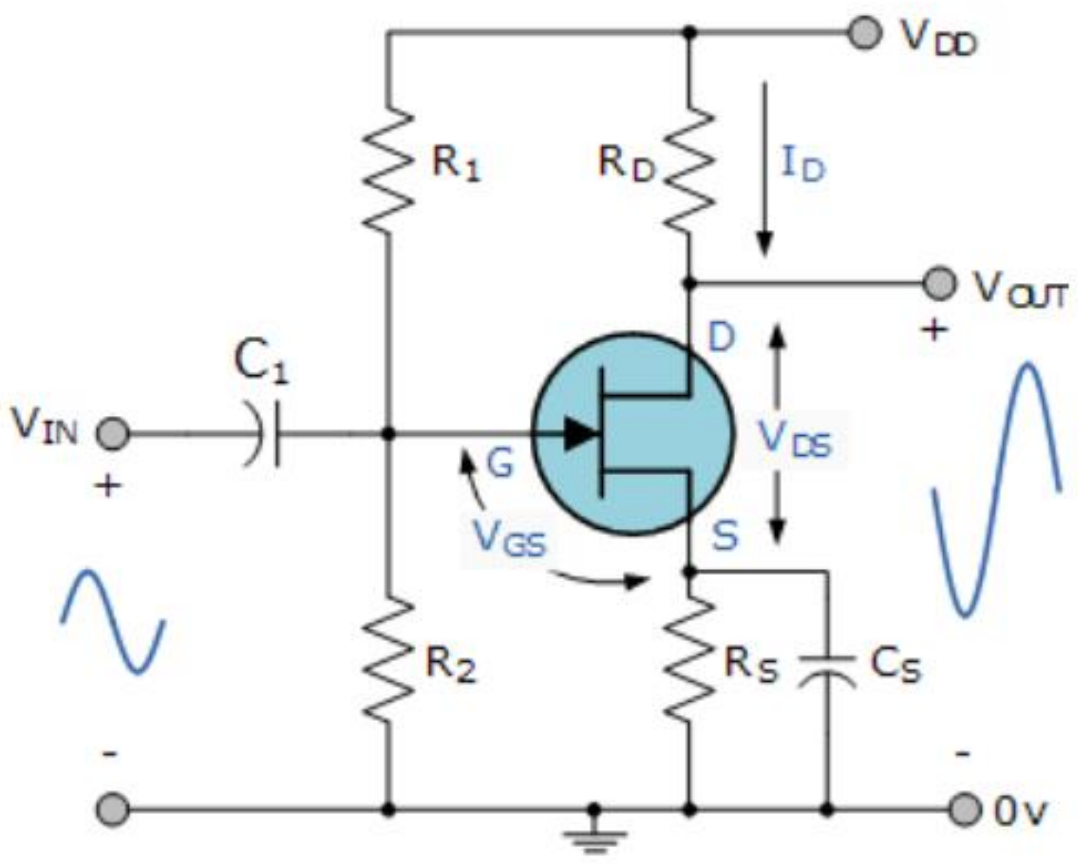
$$V_{out} = \frac{1}{\sqrt{1 + \omega^2 R^2 C^2}} V_{in}$$

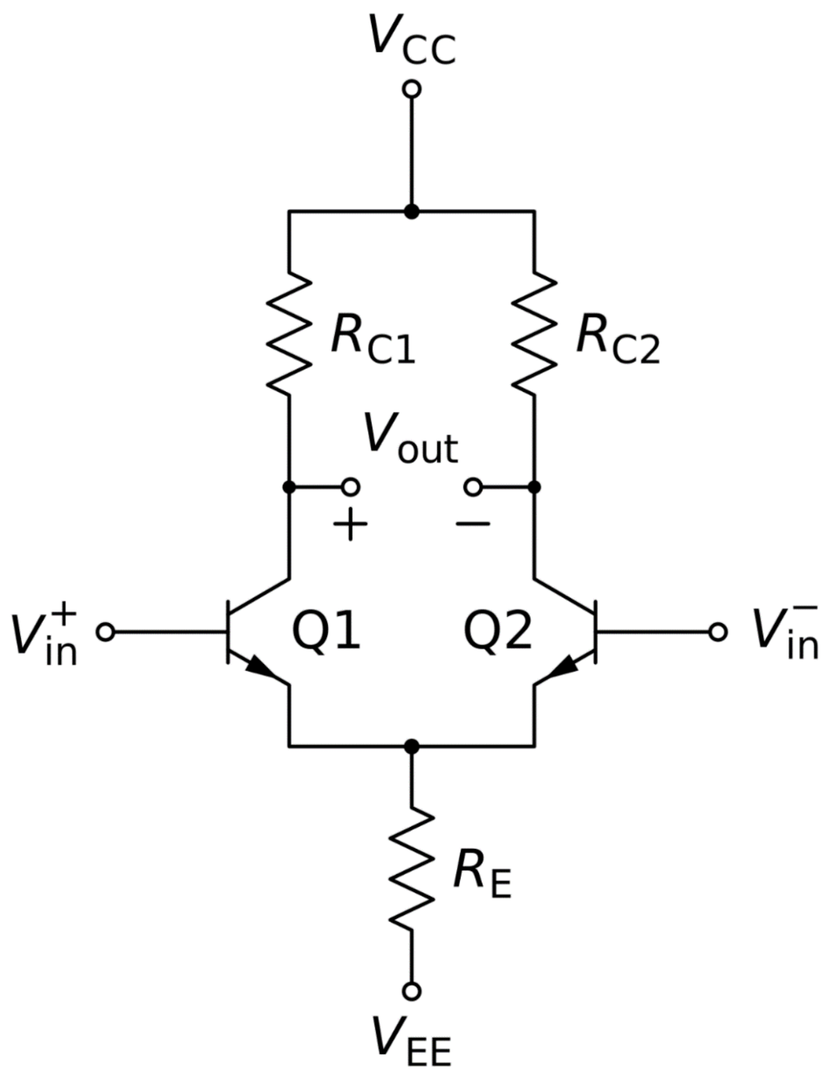


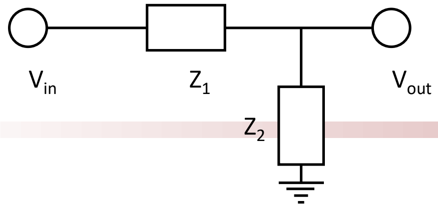
I/V Converter



Differential Amplifier







Low Pass Filter

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$$V_{out} = \frac{\frac{1}{i\omega C}}{R + \frac{1}{i\omega C}} V_{in}$$

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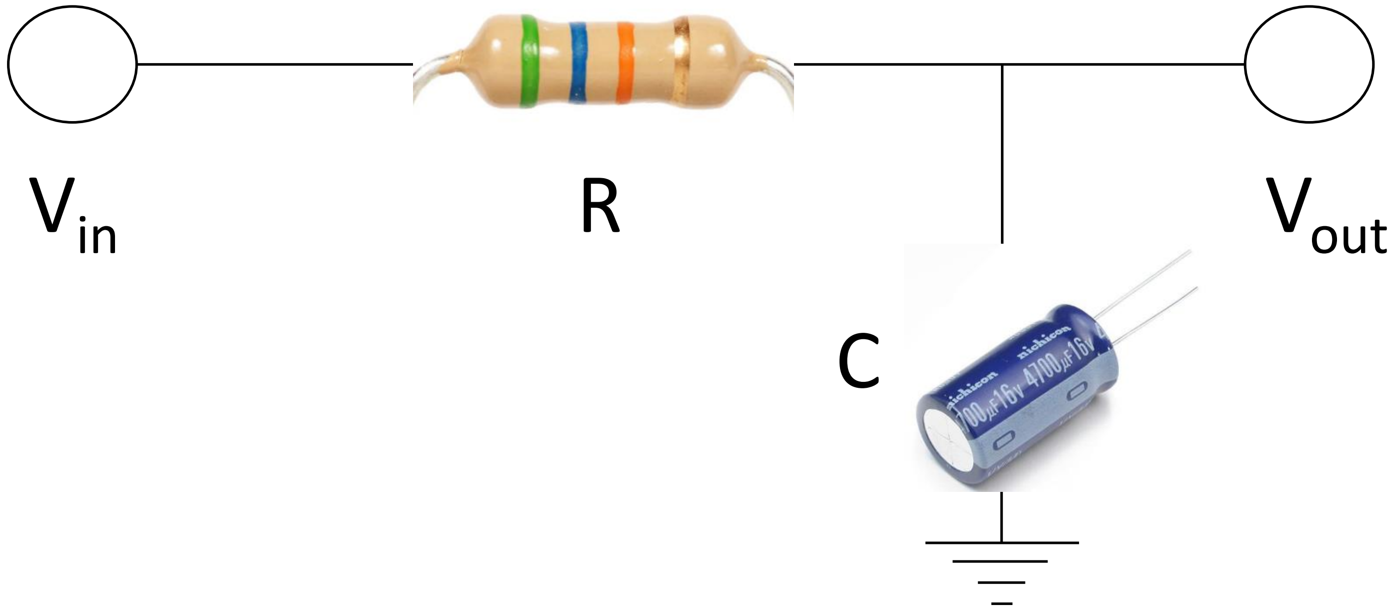
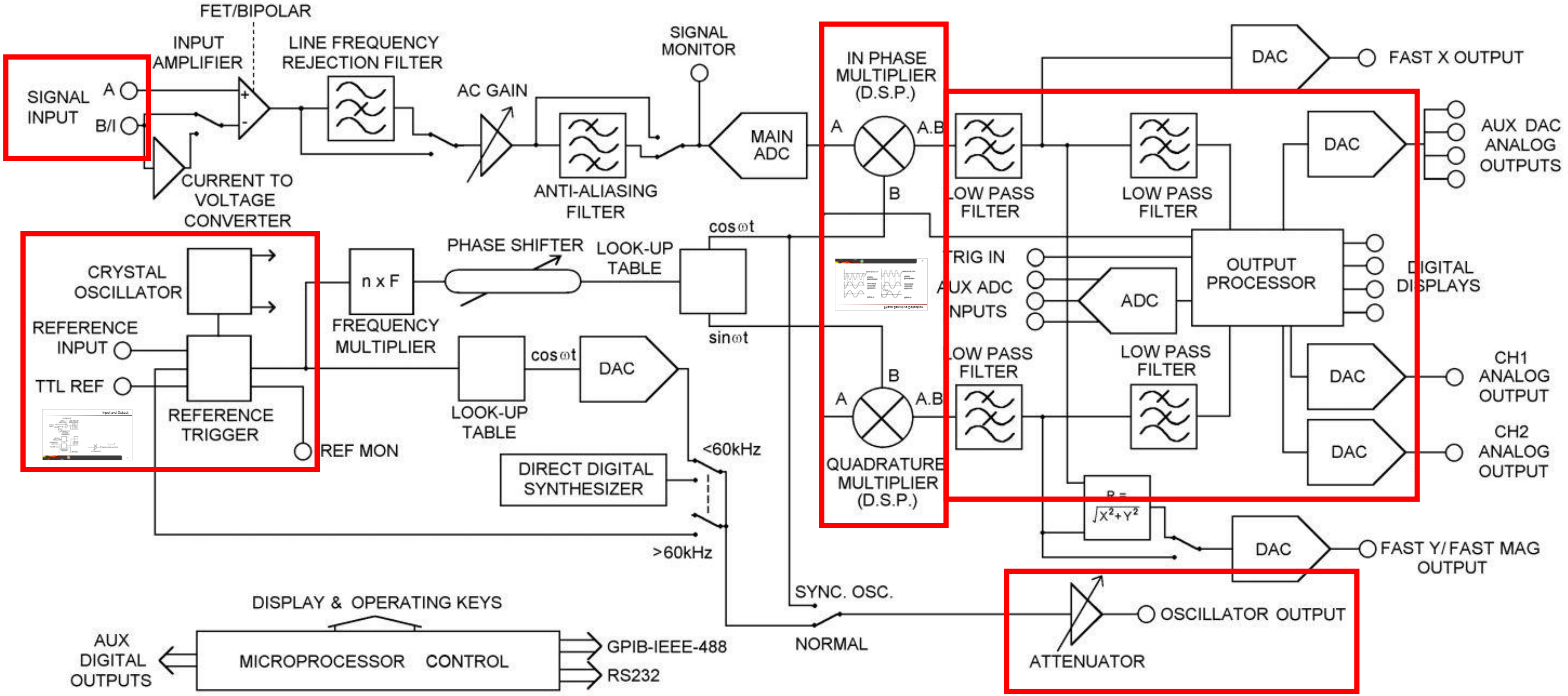
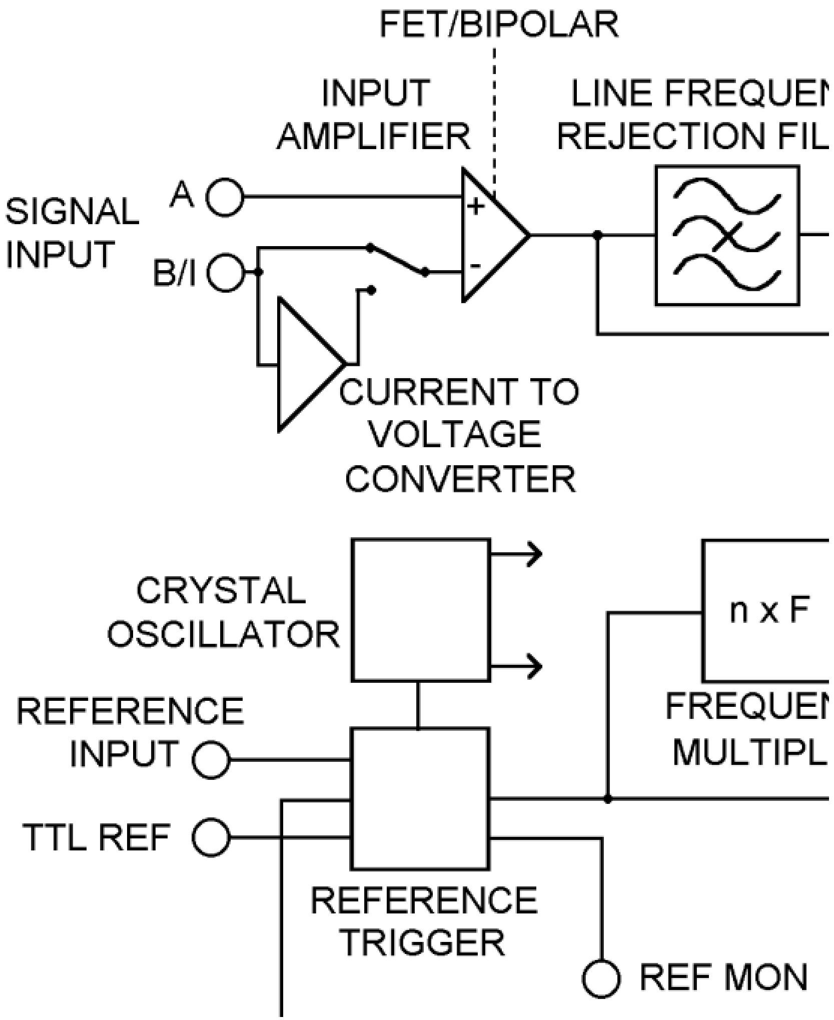


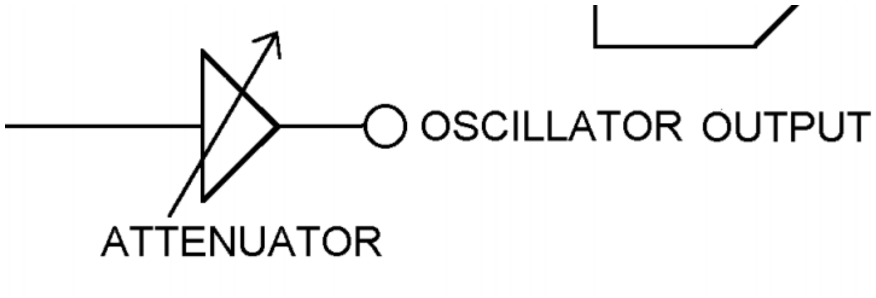
Lock-In



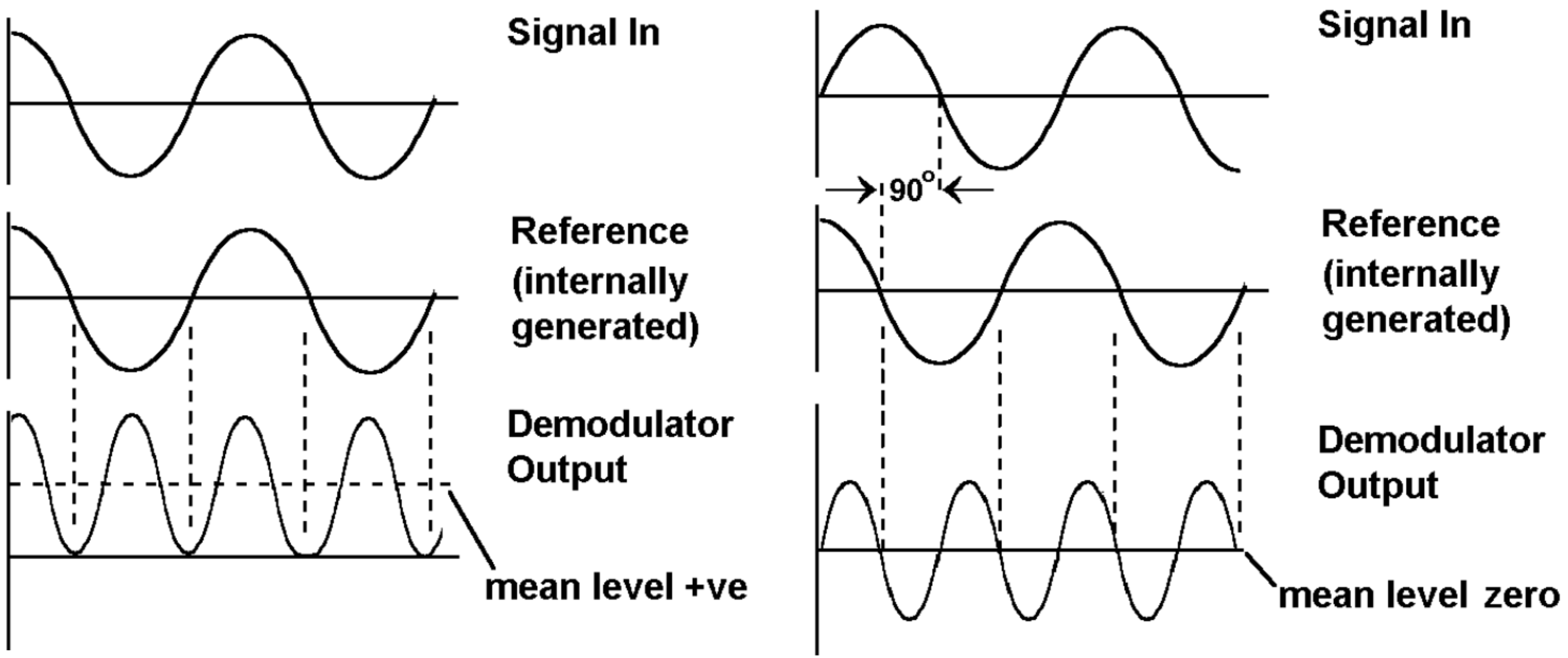
FET/BIPOLAR
INPUT AMPLIFIER
LINE FREQUENCY REJECTION FILTER
SIGNAL MONITOR
SIGNAL INPUT
A
B/I
AC GAIN
CURRENT TO VOLTAGE CONVERTER
ANTI-ALIASING FILTER
MAIN ADC
IN PHASE MULTIPLIER (D.S.P.)
A
A.B
B
LOW PASS FILTER
LOW PASS FILTER
DAC
FAST X OUTPUT
DAC
AUX DAC ANALOG OUTPUTS
CRYSTAL OSCILLATOR
n x F
FREQUENCY MULTIPLIER
PHASE SHIFTER
LOOK-UP TABLE
cosωt
sinωt
TRIG IN
AUX ADC INPUTS
ADC
OUTPUT PROCESSOR
DIGITAL DISPLAYS
REFERENCE INPUT
TTL REF
REFERENCE TRIGGER
REF MON
cosωt
DAC
LOOK-UP TABLE
LOW PASS FILTER
LOW PASS FILTER
B
A
A.B
QUADRATURE MULTIPLIER (D.S.P.)
DAC
CH1 ANALOG OUTPUT
DAC
CH2 ANALOG OUTPUT
<60kHz
DIRECT DIGITAL SYNTHESIZER
>60kHz
$R = \sqrt{X^2+Y^2}$
DAC
FAST Y/ FAST MAG OUTPUT
SYNC. OSC.
NORMAL
ATTENUATOR
OSCILLATOR OUTPUT
DISPLAY & OPERATING KEYS
AUX DIGITAL OUTPUTS
MICROPROCESSOR CONTROL
GPIB-IEEE-488
RS232

Input and Output





Phase Sensitive Detection



Phase Sensitive Detection – Mathematical View

$$V_{in} = A\cos(\omega t) \text{ with } \omega = 2\pi f$$

$$V_{ref} = B\cos(\omega t + \Theta)$$

$$V_{psd} = A\cos(\omega t) * B\cos(\omega t + \Theta)$$

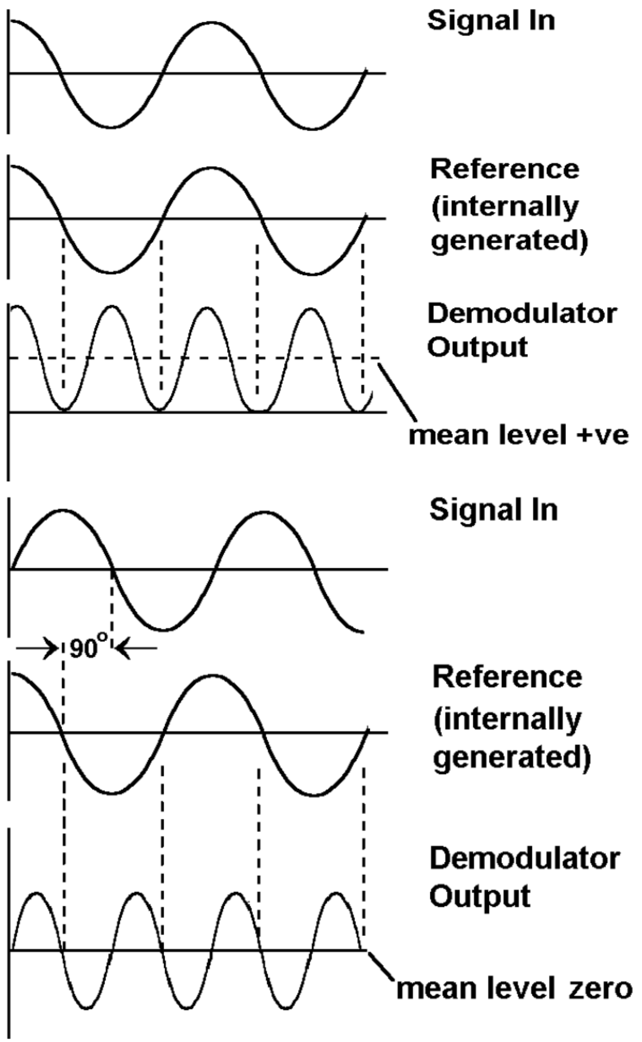
$$= {}^{1}/_{2}\, AB\cos(\Theta) + {}^{1}/_{2}\, AB\cos(2\omega t + \Theta)$$

Output signal proportional to

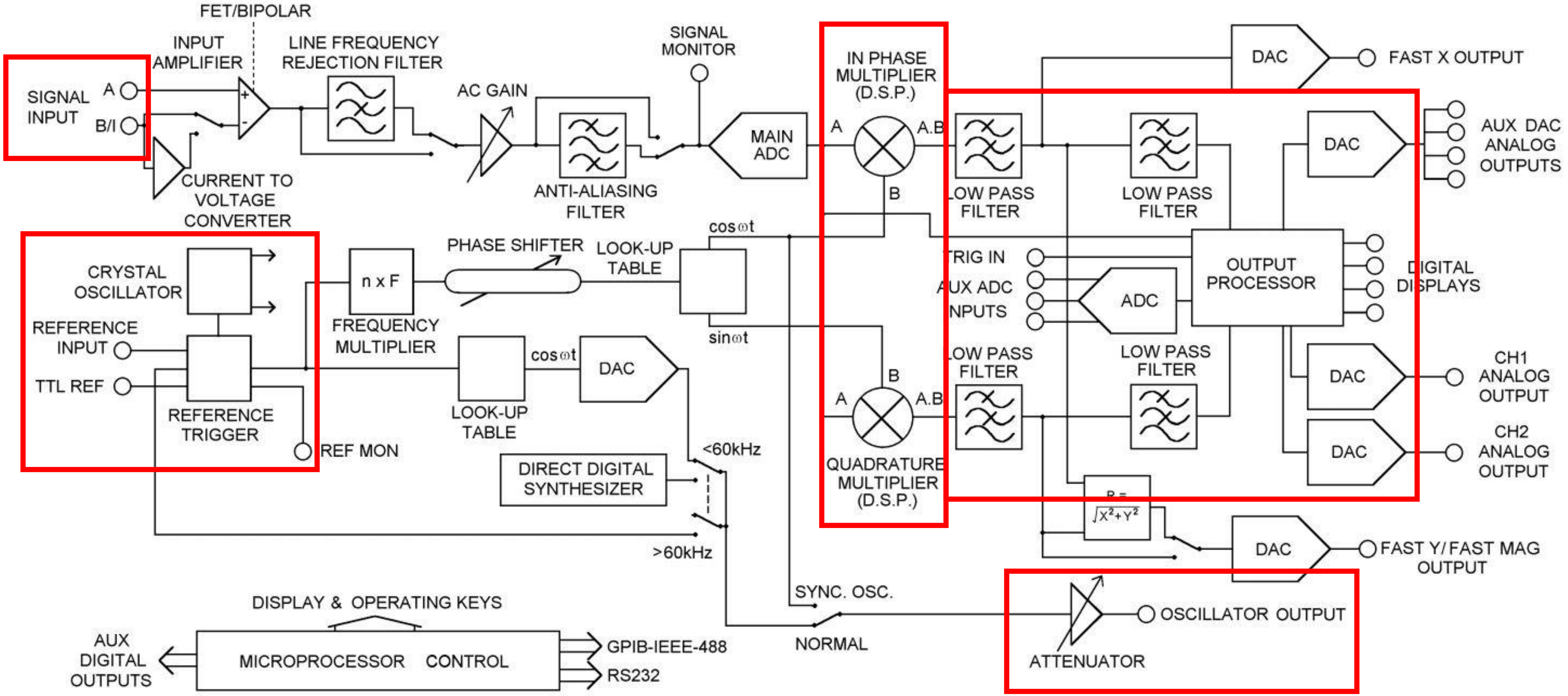
- magnitude of A
- cosine of the angle between output and reference signal

and modulated by

- components at twice the reference frequency $(2\omega t)$



Backup Section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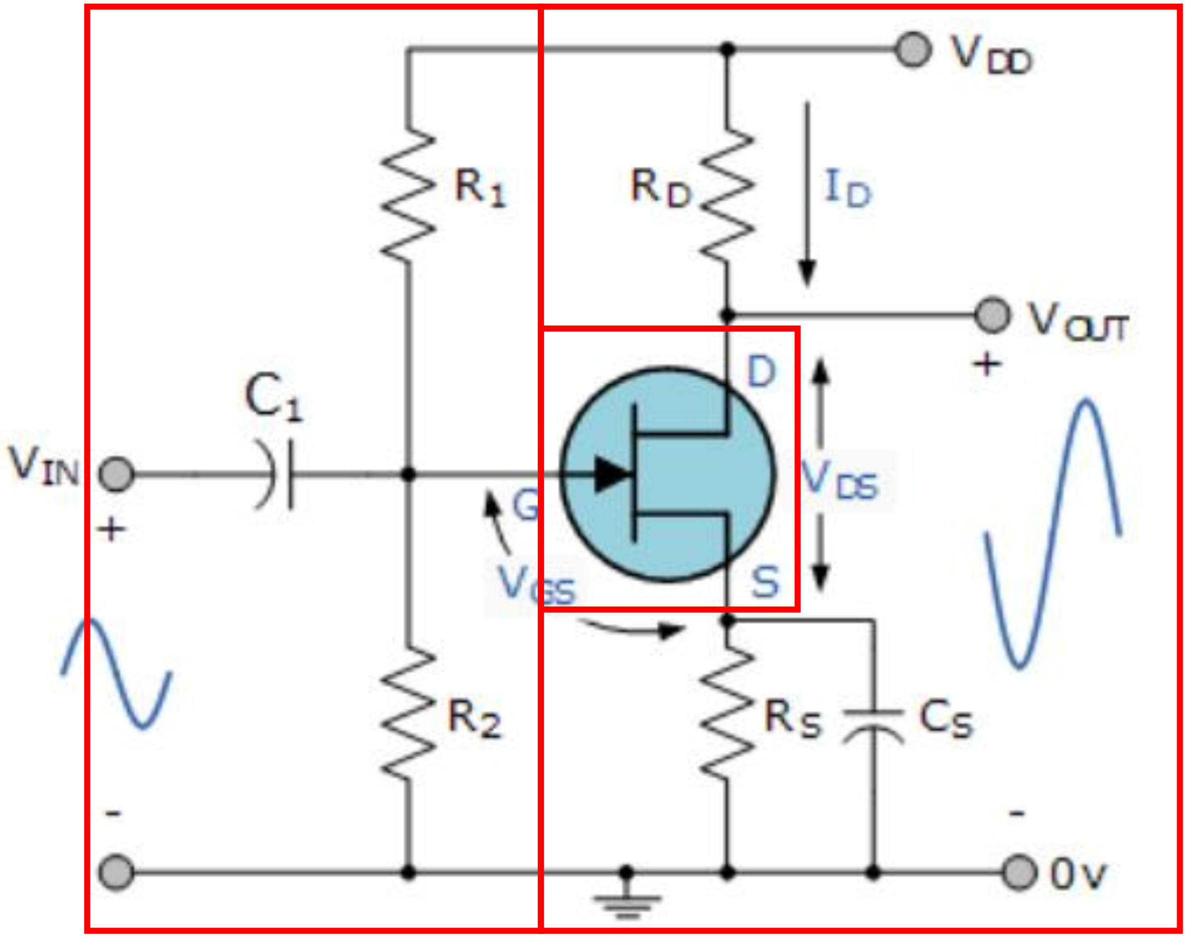

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