# Experiment 1 - Familiarization with NGSPICE and Lab Equipment

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EE230 Analog (Circuits) Lab

2021-22/I

# NGSPICE Familiarization

- Why NGSPICE? Why not LTSPICE, PSPICE,…
- NGSPICE -  for understanding basic concepts better
  - Effect of device parameters on the circuit performance
- Comparison – Analysis, Simulation, Experiment
- Which one to trust? Why?

# Why Analysis and Simulation Differ with the Measured Results?

- Analysis
  - Uses models
  - Involves lots of approximations
  - If so, why to use analysis?

- Simulation
  - Uses models
  - Should use the right models
  - If so, why to use simulation?

# Experiments

- If carefully done should match closely to analysis and simulations

- All components have manufacturing tolerances
  - Resistors – 5%, 10% (0.1% resistors also available)

- Capacitors – several types
  - Named as per the dielectric used
  - Ceramic and Electrolytic capacitors – most commonly used
  - Paper, Mica, Polyester, Nylon – used in precision or high voltage applications

# Youtube Recordings – done for EE113-2020

- Expt 0 – Familiarization
- Expt 1 – DC Power Supply
- Expt 2 – Opamp circuits (Linear and Non-linear)

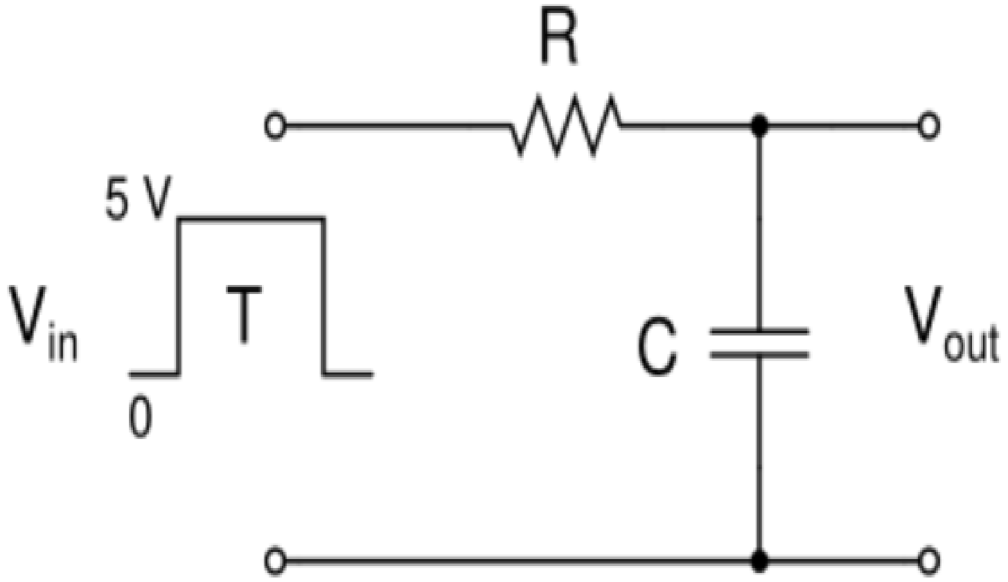
# Expt 1 - Familiarization

- NGSPICE simulation – RC and RLC Circuits
- Lab Equipment

# RC Switching Circuits

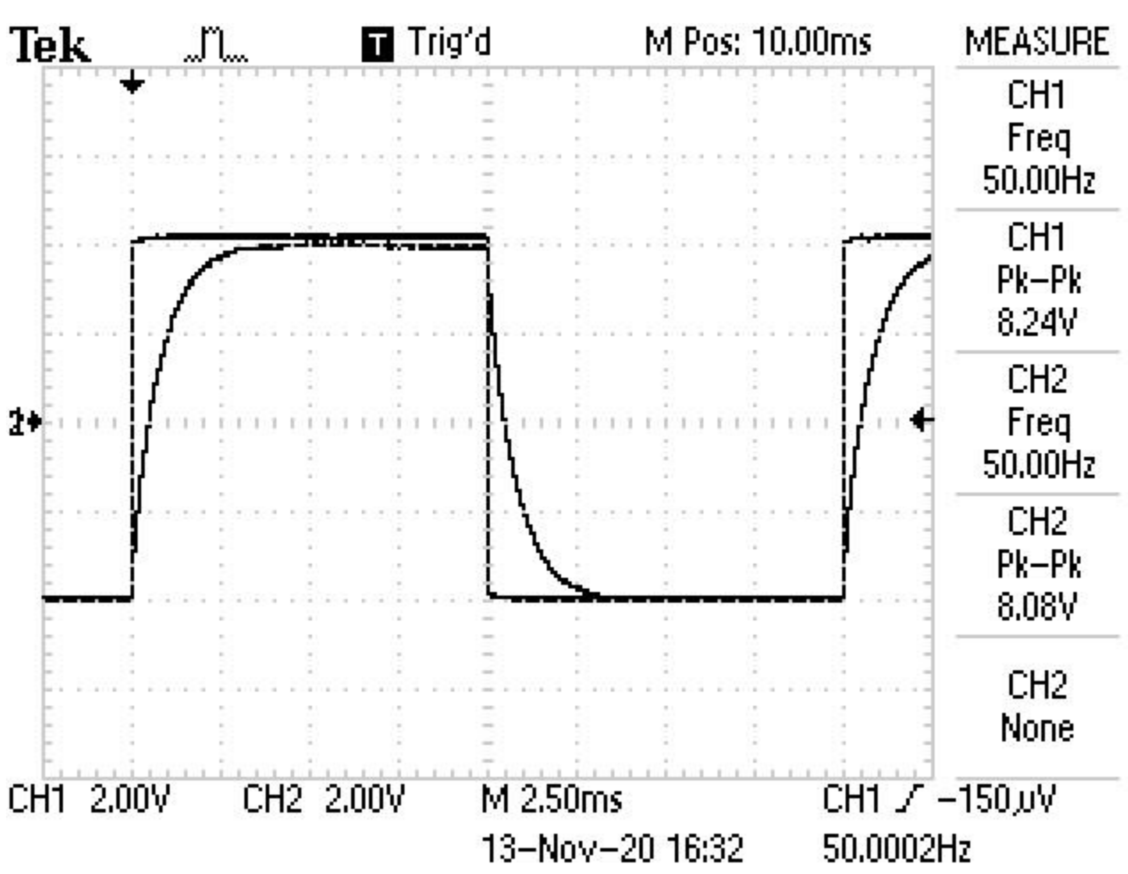
- RC Integrator
- RC Differentiator

# RC Integrator

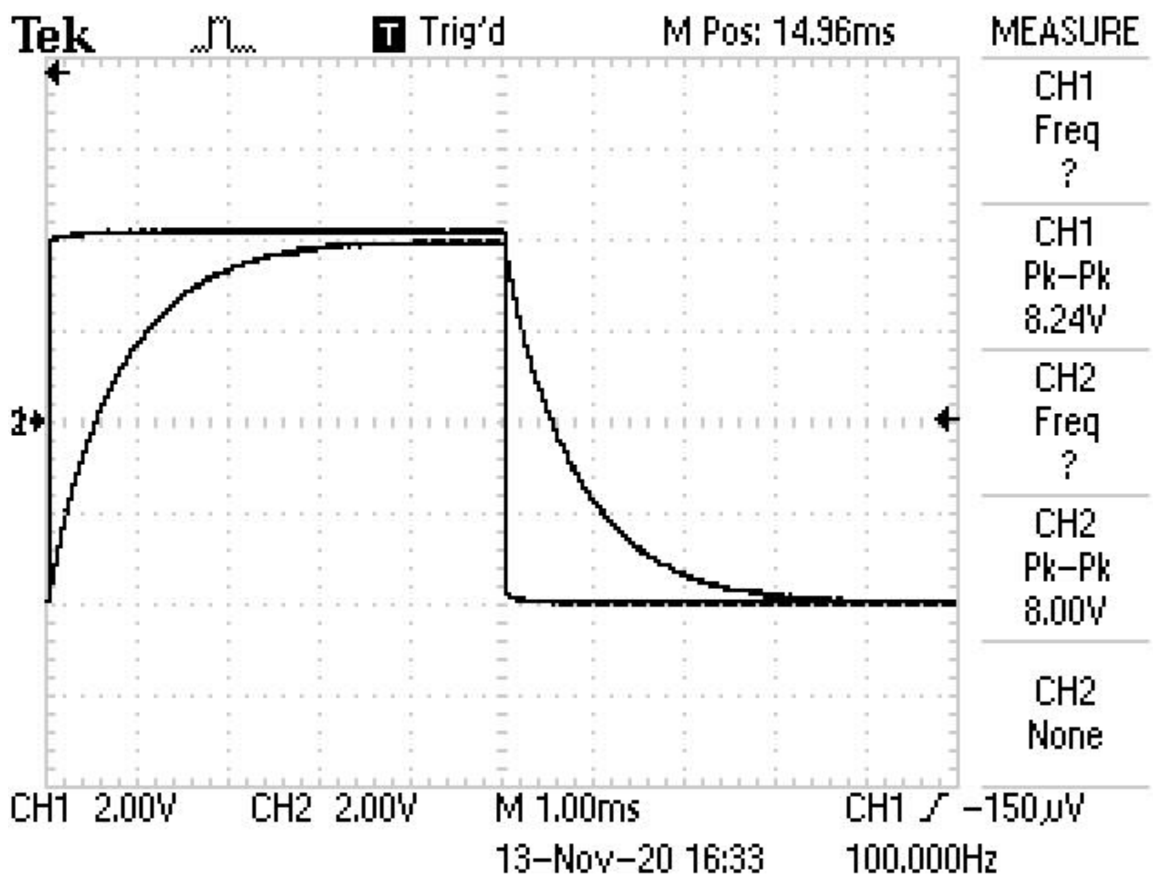



- R = 10 kΩ and C = 0.1 μF

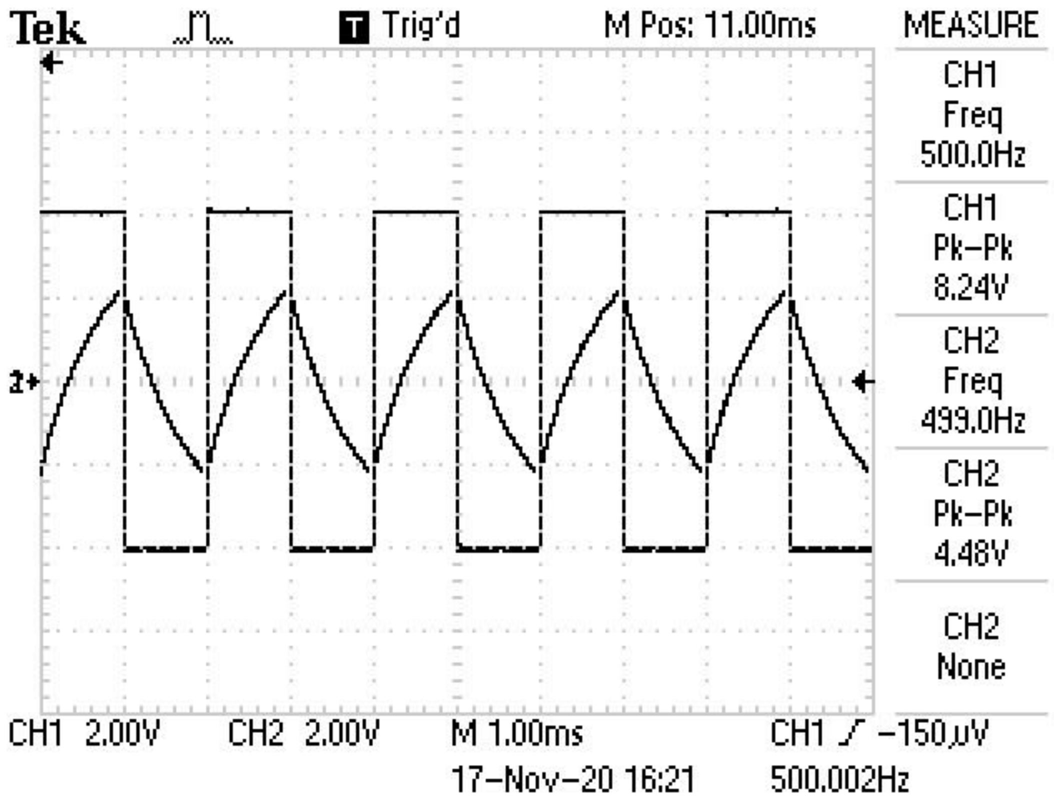
- Cases:
- i) $T = 10\,\tau$ ;
- ii) $T = 5\,\tau$ ;
- iii) $T = 1\,\tau$ ;
- iv) $T = 0.5\,\tau$ ;
- v) $T = 0.1\,\tau$ ;
- vi) $T = 0.05\,\tau$

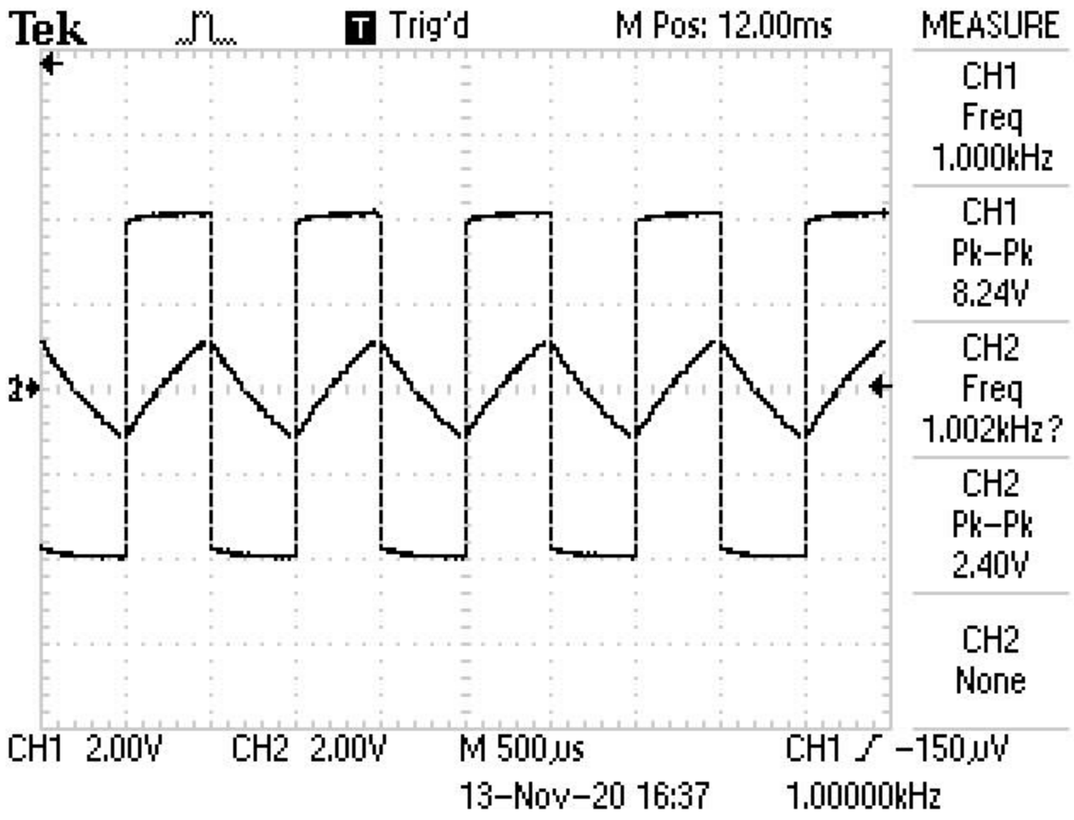

Tek
Trig'd
M Pos: 10.00ms
MEASURE
CH1
Freq
50.00Hz
CH1
Pk-Pk
8.24V
CH2
Freq
50.00Hz
CH2
Pk-Pk
8.08V
CH2
None
CH1 2.00V
CH2 2.00V
M 2.50ms
CH1 ∫ -150µV
13-Nov-20 16:32
50.0002Hz

i) T = 10 τ


Tek
Trig'd
M Pos: 14.96ms
MEASURE
CH1
Freq
?
CH1
Pk-Pk
8.24V
CH2
Freq
?
CH2
Pk-Pk
8.00V
CH2
None
CH1 2.00V
CH2 2.00V
M 1.00ms
CH1 ∫ -150µV
13-Nov-20 16:33
100.000Hz

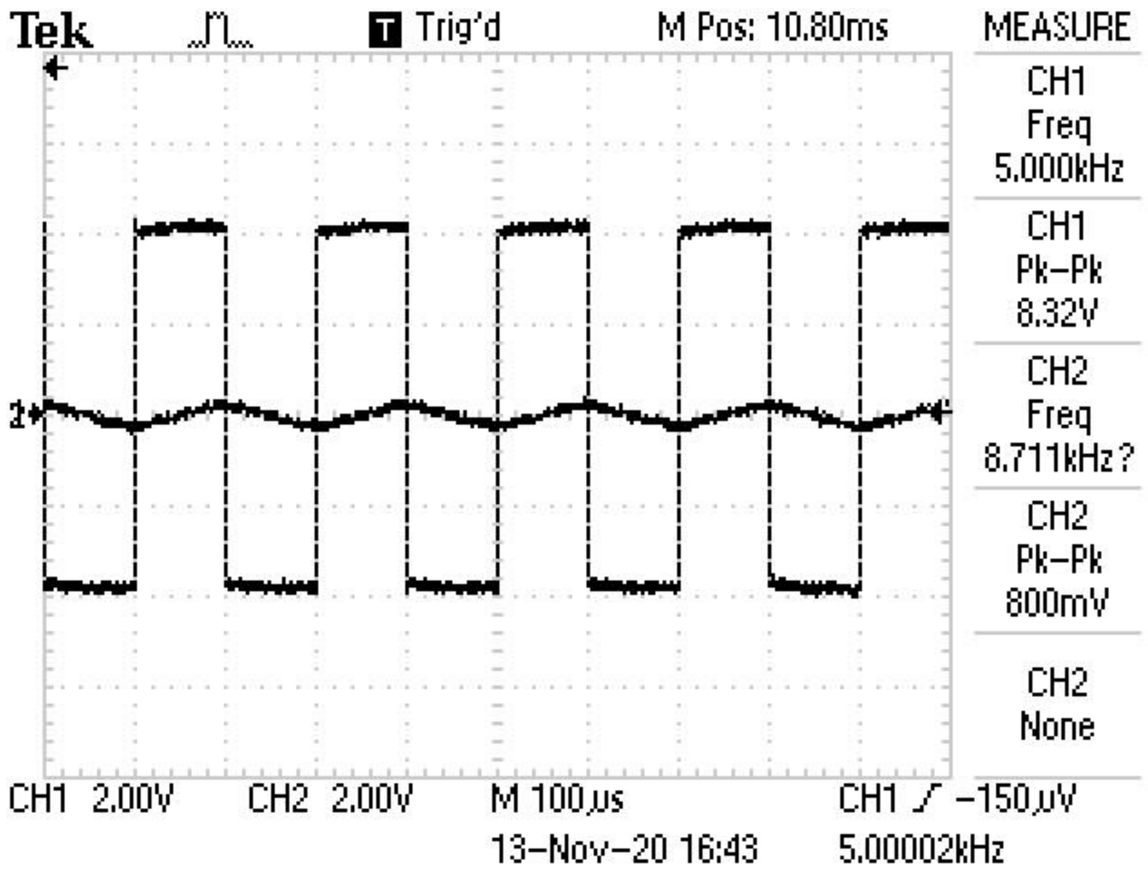
ii) T = 5 τ



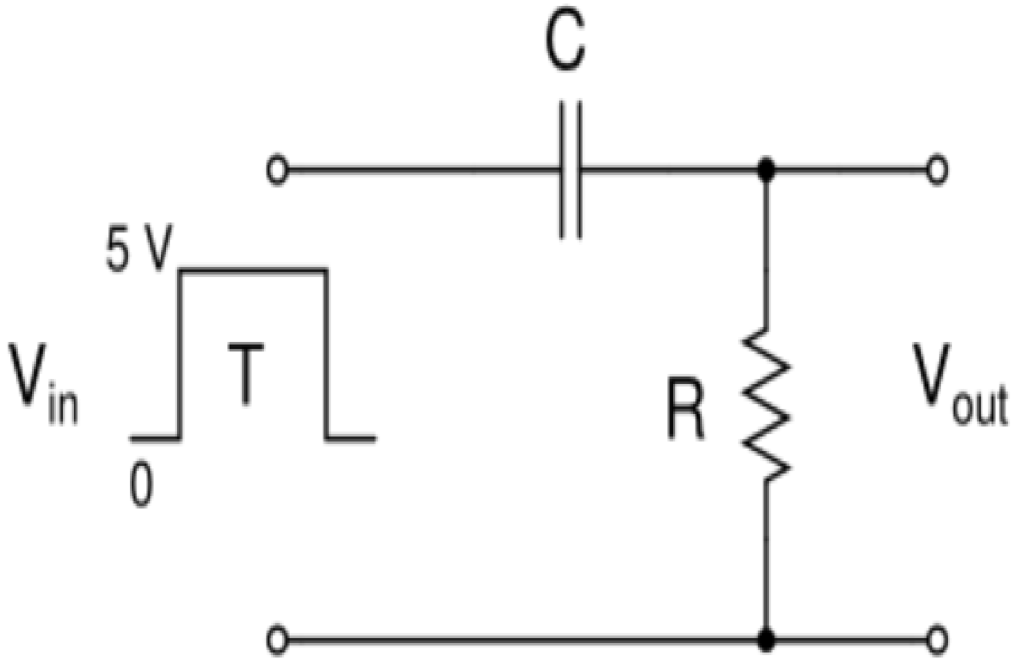

iii) T = 1 τ

iv) T = 0.5 τ

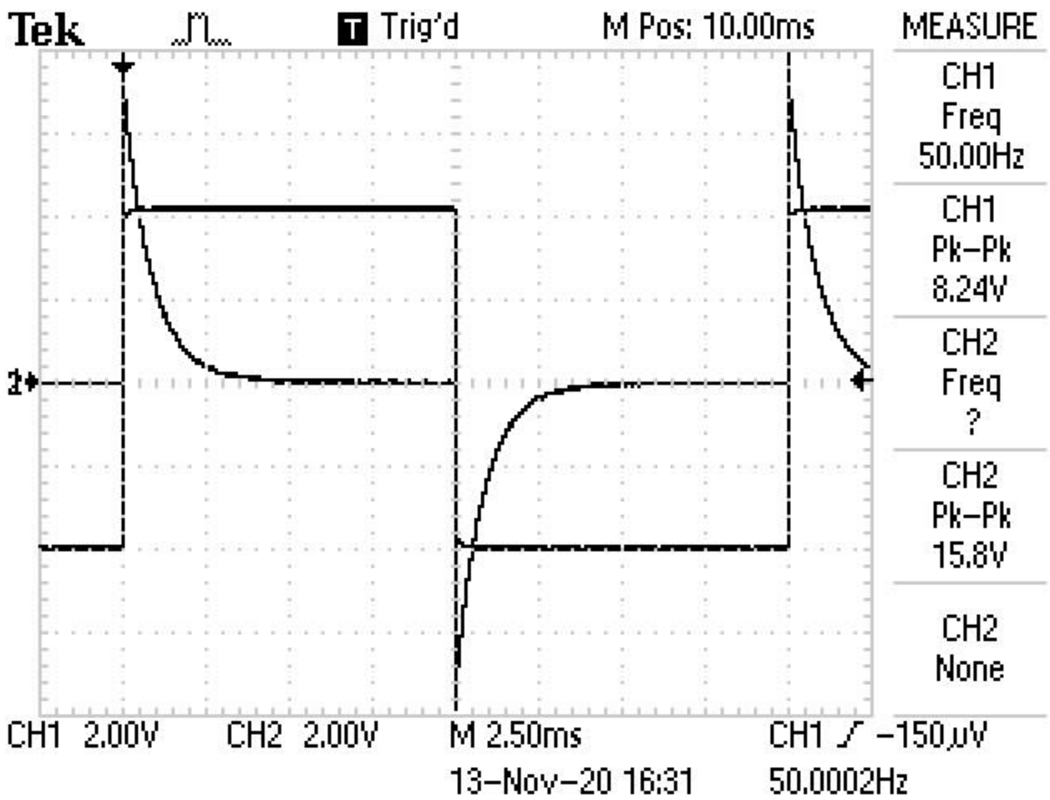

Tek
Trig'd
M Pos: 10.80ms
MEASURE
CH1
Freq
5.000kHz
CH1
Pk−Pk
8.32V
CH2
Freq
8.711kHz?
CH2
Pk−Pk
800mV
CH2
None
CH1 2.00V
CH2 2.00V
M 100µs
CH1 −150µV
13−Nov−20 16:43
5.00002kHz

v) T = 0.1 τ

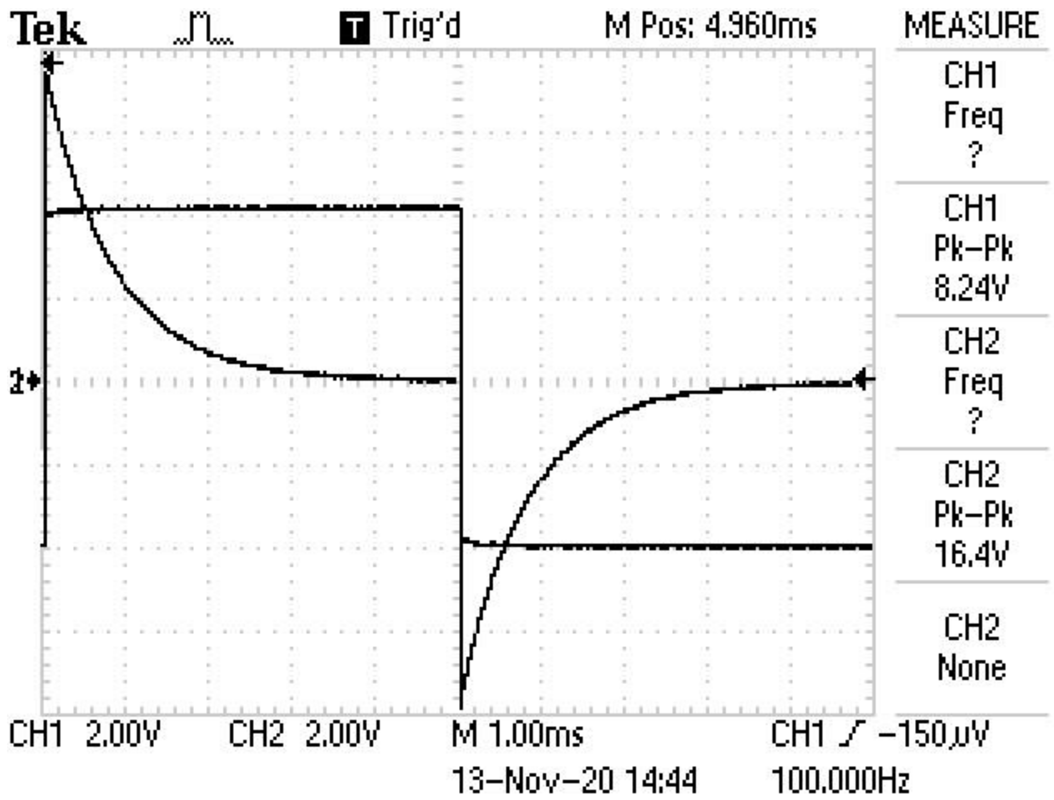
# RC Differentiator



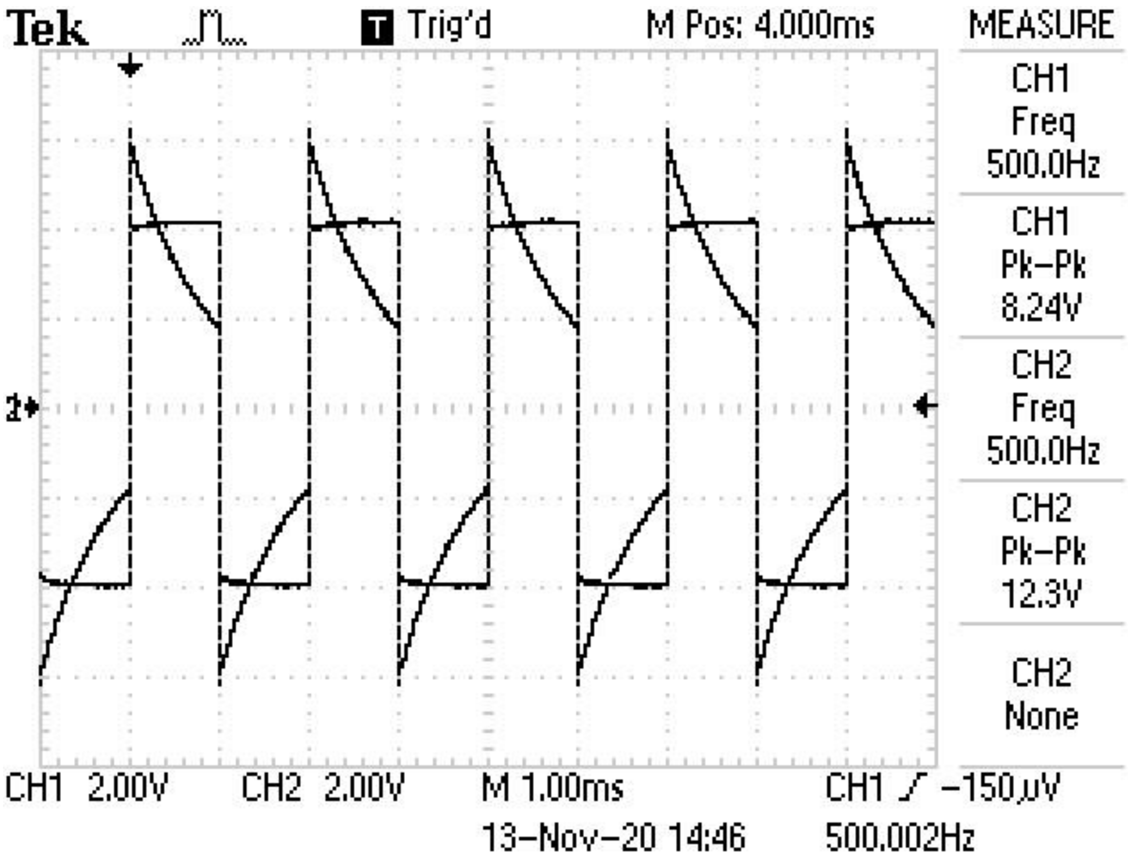

- R = 10 kΩ and C = 0.1 μF
- Cases:
- i) $T = 10\,\tau$ ;
- ii) $T = 5\,\tau$ ;
- iii) $T = 1\,\tau$ ;
- iv) $T = 0.5\,\tau$ ;
- v) $T = 0.1\,\tau$ ;
- vi) $T = 0.05\,\tau$


Tek
Trig'd
M Pos: 10.00ms
MEASURE
CH1
Freq
50.00Hz
CH1
Pk–Pk
8.24V
CH2
Freq
?
CH2
Pk–Pk
15.8V
CH2
None
CH1 2.00V
CH2 2.00V
M 2.50ms
CH1 ∫ −150μV
13–Nov–20 16:31
50.0002Hz

i) T = 10 τ


Tek
Trig'd
M Pos: 4.960ms
MEASURE
CH1
Freq
?
CH1
Pk–Pk
8.24V
CH2
Freq
?
CH2
Pk–Pk
16.4V
CH2
None
CH1 2.00V
CH2 2.00V
M 1.00ms
CH1 ∫ −150μV
13–Nov–20 14:44
100.000Hz

ii) T = 5 τ



Tek
Trig'd
M Pos: 4.000ms
MEASURE
CH1
Freq
500.0Hz
CH1
Pk-Pk
8.24V
CH2
Freq
500.0Hz
CH2
Pk-Pk
12.3V
CH2
None
CH1 2.00V
CH2 2.00V
M 1.00ms
13-Nov-20 14:46
CH1 -150μV
500.002Hz


iii) T = 1 τ

# RC Filters

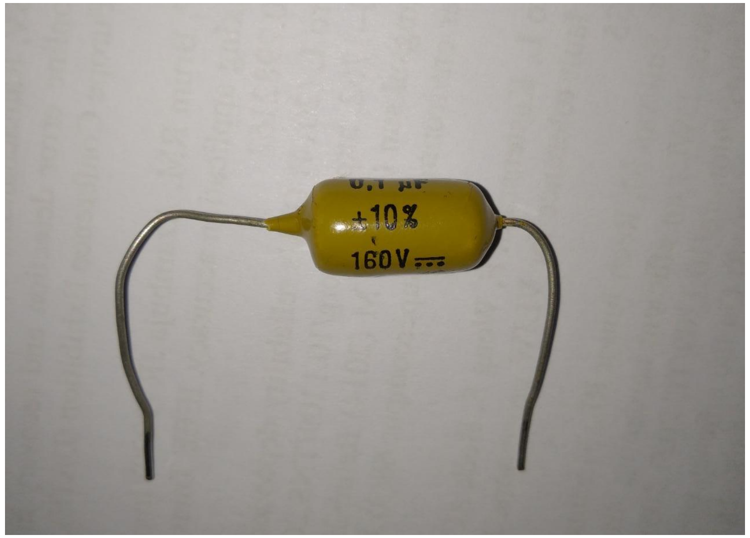
- RC Lowpass filter
- RC Highpass filter
- RC Bandpass filter

# RC Filter Circuits

- Easy to design and implement

- Not good for many applications

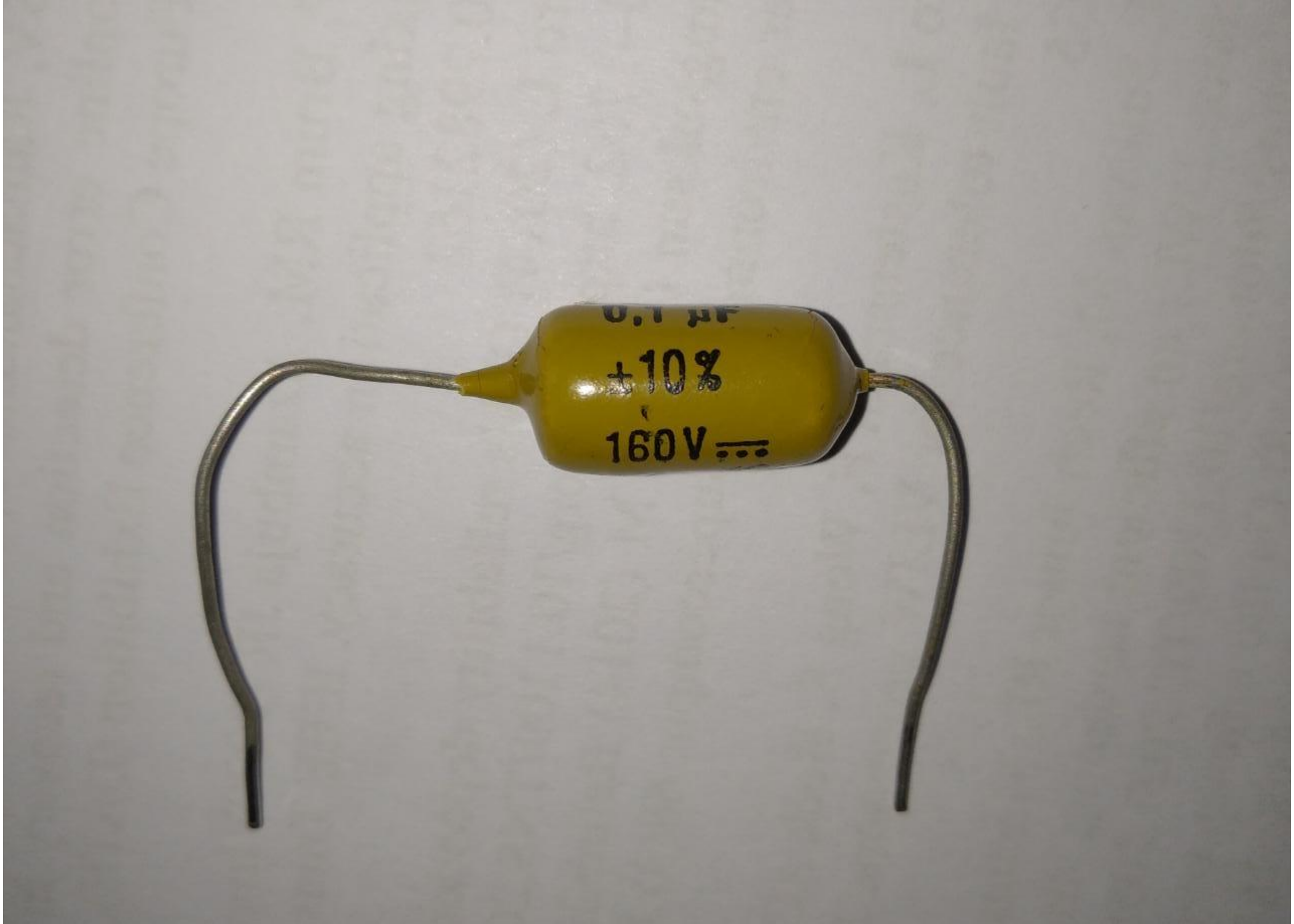
- Capacitors – several types
  - Named as per the dielectric used
  - Ceramic and Electrolytic capacitors – most commonly used
  - Paper, Mica, Polyester, Nylon – used in precision or high voltage applications




Paper Capacitor

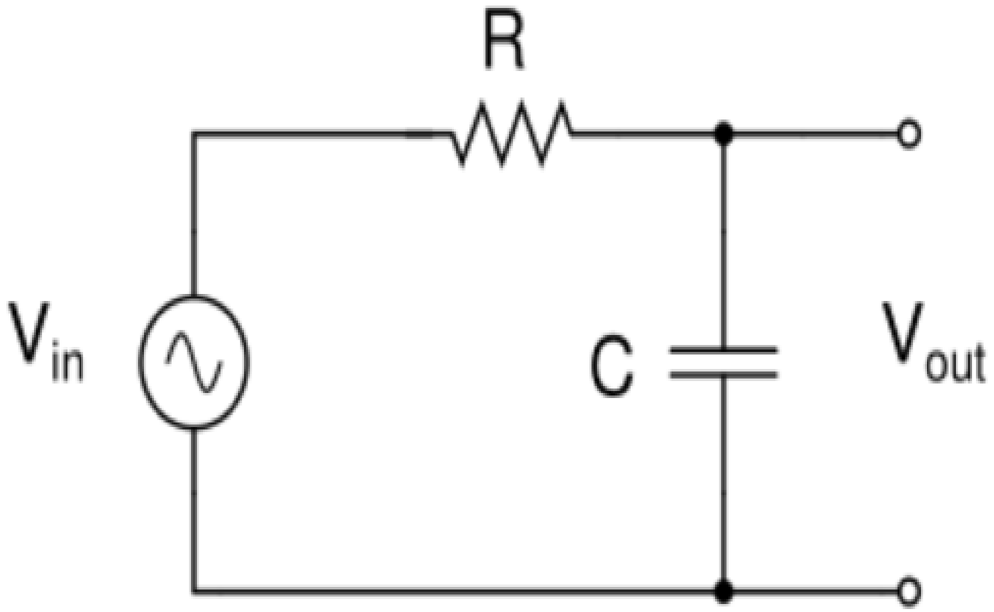

Ceramic Capacitor


Nylon/Polyster Capacitor



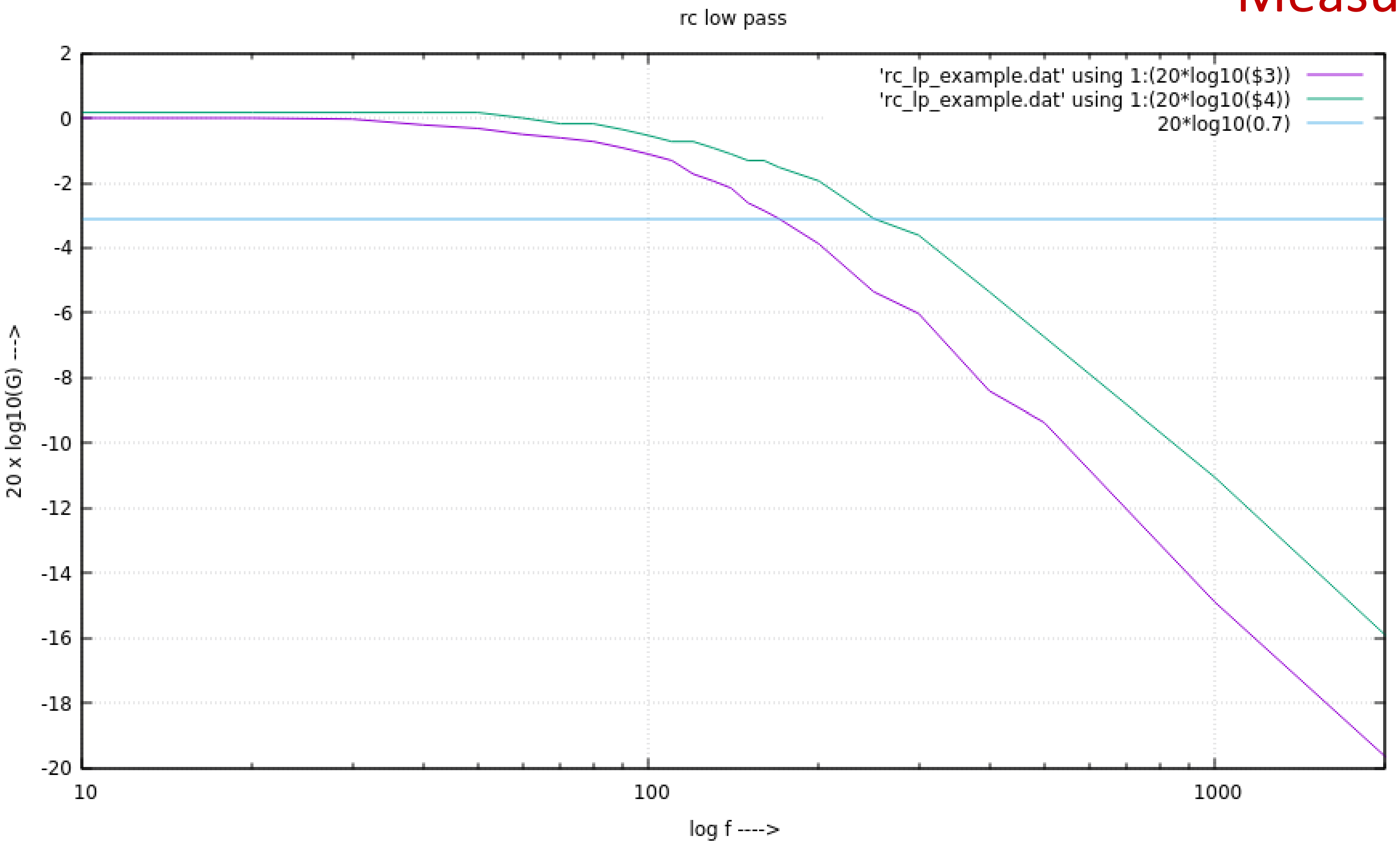

Paper Capacitor

# RC Lowpass Filter




R = 10 kΩ,  C = 0.1 μF.

# Measured Results




Nominal values:

R = 10 kΩ and

C = 0.1 μF

Actual:

R = 9.7 kΩ

C = ??

Green: Ceramic Capacitor

Light purple: Paper Capacitor (10% tolerance)

- Theory

$f_c = 1/(2\pi RC)$

($R$ = 10 kΩ, $C$ = 0.1 μF)

- $f_c$ = 159.2 Hz

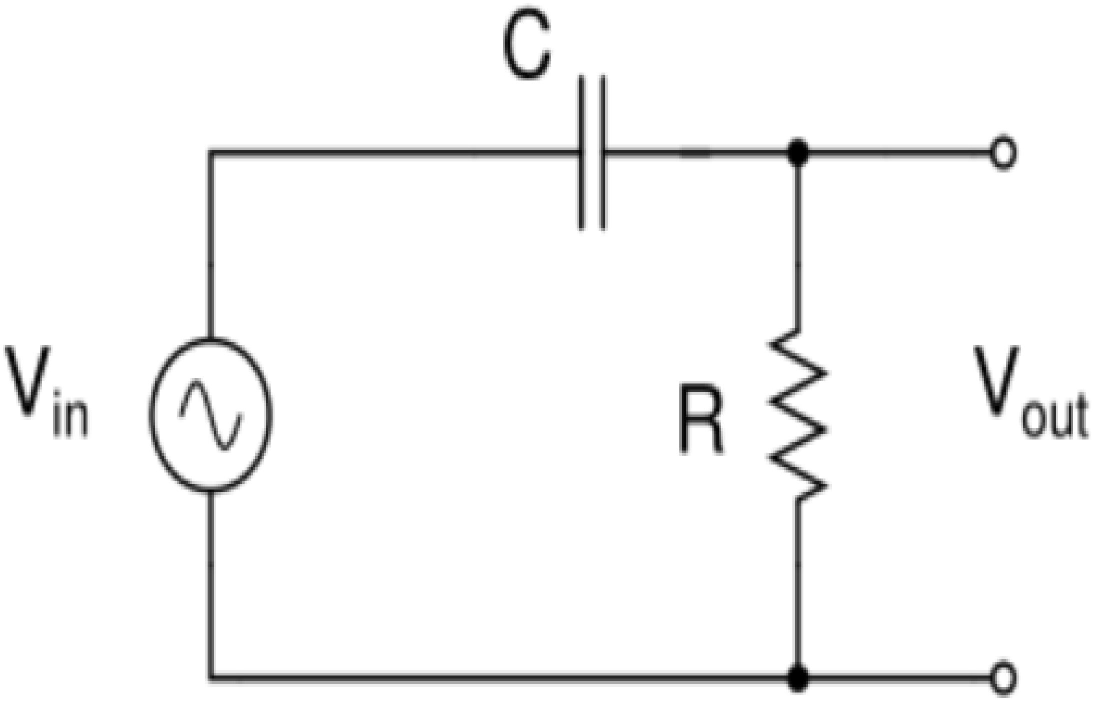
Note the difference in $f_c$ →

| RC LPF | Paper cap(10%) | | Ceramic cap |
|---|---|---|---|
| freq | Vin(pk-pk) | Vout(pk-pk) V | Vout(pk-pk) V |
| 10 | 1 | 1 | 1.02 |
| 20 | 1 | 1 | 1.02 |
| 30 | 1 | 0.996 | 1.02 |
| 40 | 1 | 0.976 | 1.02 |
| 50 | 1 | 0.964 | 1.02 |
| 60 | 1 | 0.944 | 1 |
| 70 | 1 | 0.932 | 0.98 |
| 80 | 1 | 0.92 | 0.98 |
| 90 | 1 | 0.9 | 0.96 |
| 100 | 1 | 0.88 | 0.94 |
| 110 | 1 | 0.86 | 0.92 |
| 120 | 1 | 0.82 | 0.92 |
| 130 | 1 | 0.8 | 0.9 |
| 140 | 1 | 0.78 | 0.88 |
| 150 | 1 | 0.74 | 0.86 |
| 160 | 1 | 0.72 | 0.86 |
| 170 | 1 | 0.7 | 0.84 |
| 200 | 1 | 0.64 | 0.8 |
| 250 | 1 | 0.54 | 0.7 |
| 300 | 1 | 0.5 | 0.66 |
| 400 | 1 | 0.38 | 0.54 |
| 500 | 1 | 0.34 | 0.46 |
| 1000 | 1 | 0.18 | 0.28 |
| 2000 | 1 | 0.104 | 0.16 |

RC Lowpass Filter

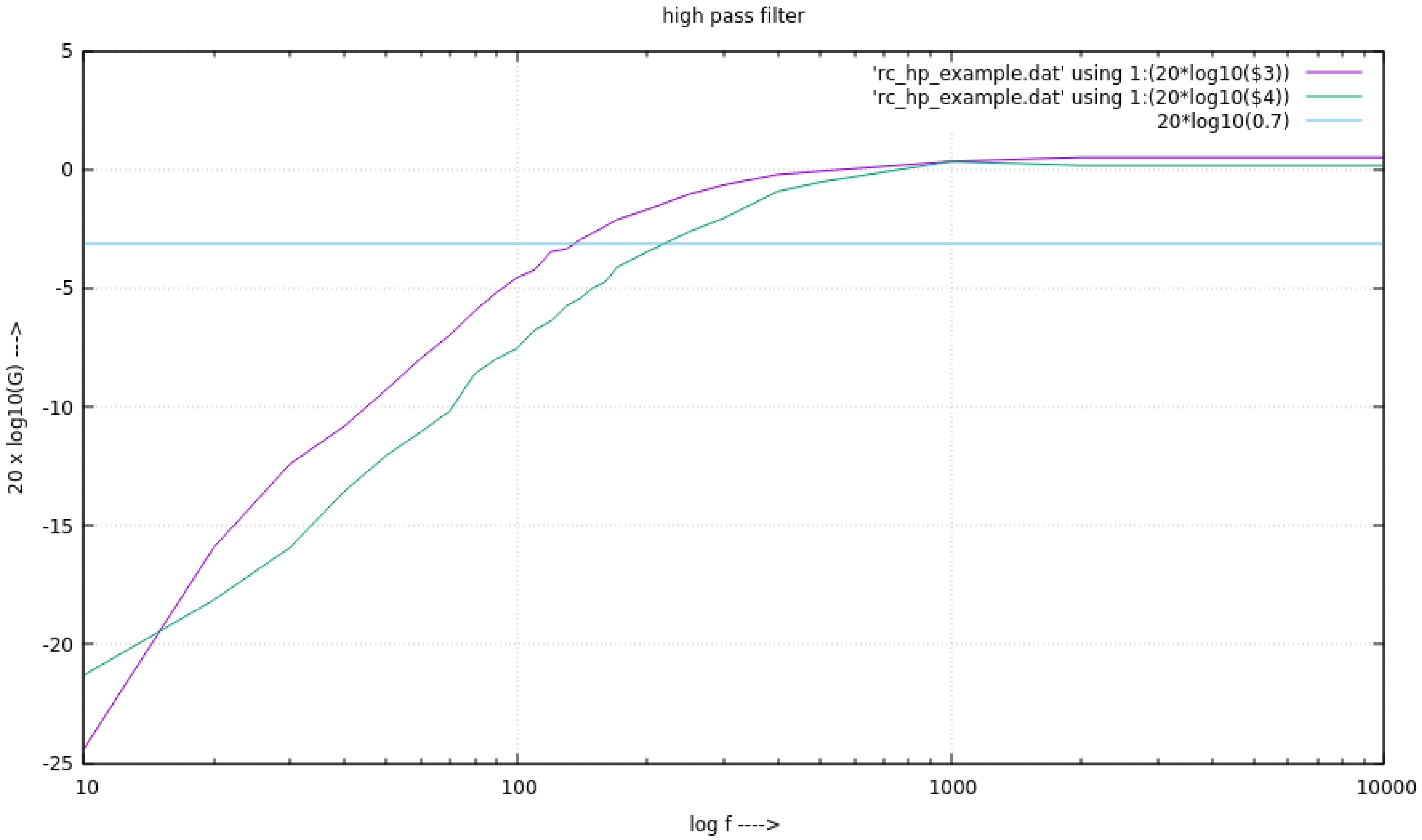
Measured values

# RC Highpass Filter




R = 10 kΩ and C = 0.1 μF

# Measured Results




Nominal values:

R = 10 kΩ and

C = 0.1 μF

Actual:

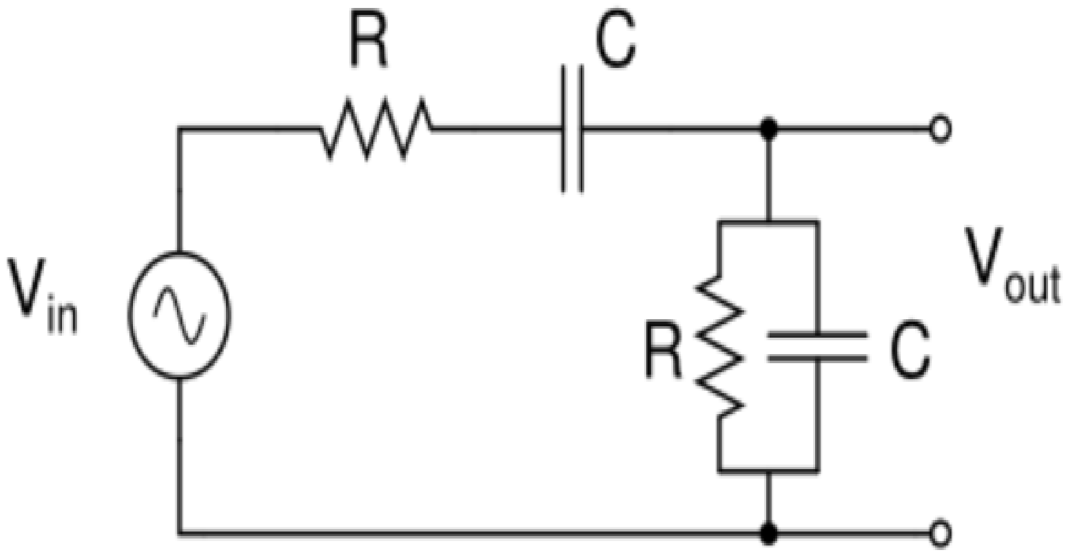
R = 9.7 kΩ

C = ??

Green: Ceramic Capacitor

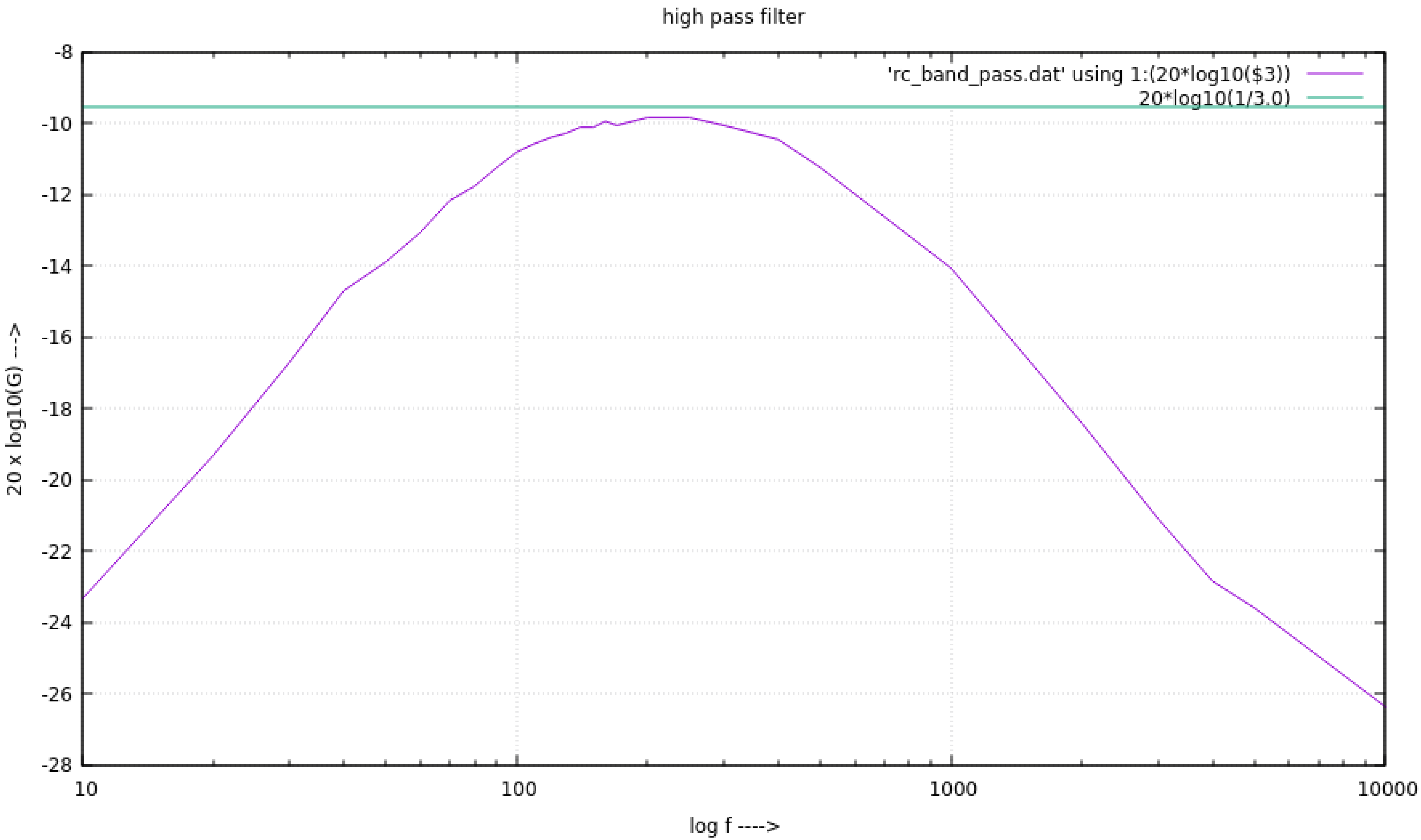
Light purple: Paper Capacitor (10% tolerance)

# RC Bandpass Filter




- R = 10 kΩ and C = 0.1 μF.
- Also called the ‘Wien network’

# Measured Results




- Nominal values:

  R = 10 kΩ and

  C = 0.1 μF

- Actual:

  R = 9.7 kΩ

  C = ??

- Peak at ω = 1/RC

- Theory

$f_c = 1/(2\pi RC)$

($R = 10\ k\Omega$, $C = 0.1\ \mu F$)

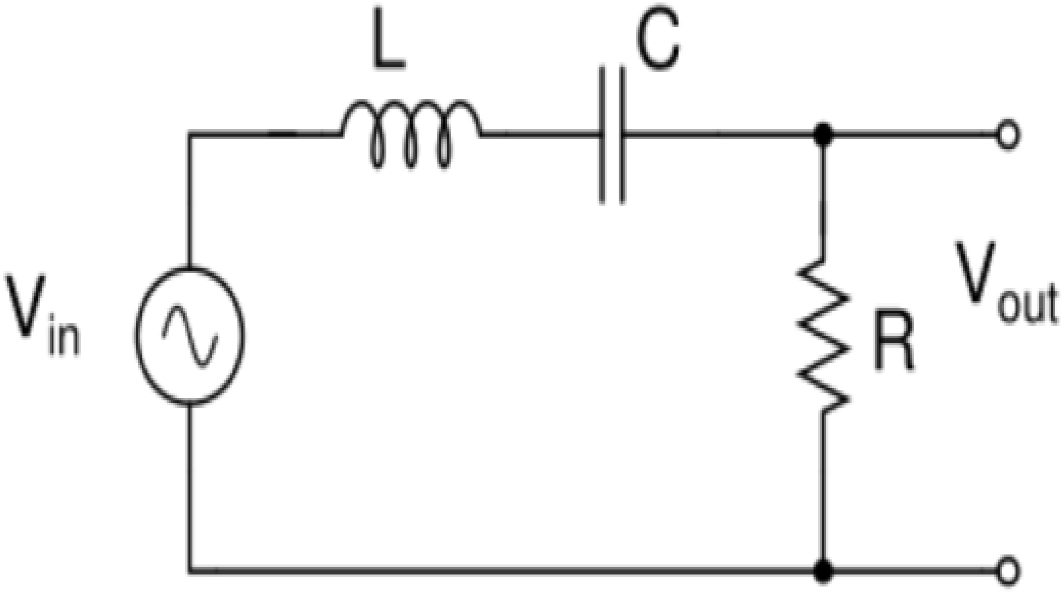
- $f_c = 159.2$ Hz

Note the difference in $f_c$

→

| RC Band Pass | | sine wave 1v(pk-pk) |
|---|---|---|
| | | Ceramic cap |
| freq | Vin(pk-pk) V | Vout(pk-pk) V |
| 10 | 1 | 0.068 |
| 20 | 1 | 0.108 |
| 30 | 1 | 0.146 |
| 40 | 1 | 0.184 |
| 50 | 1 | 0.202 |
| 60 | 1 | 0.222 |
| 70 | 1 | 0.246 |
| 80 | 1 | 0.258 |
| 90 | 1 | 0.274 |
| 100 | 1 | 0.288 |
| 110 | 1 | 0.296 |
| 120 | 1 | 0.302 |
| 130 | 1 | 0.306 |
| 140 | 1 | 0.312 |
| 150 | 1 | 0.312 |
| 160 | 1 | 0.318 |
| 170 | 1 | 0.314 |
| 200 | 1 | 0.322 |
| 250 | 1 | 0.322 |
| 300 | 1 | 0.314 |
| 400 | 1 | 0.3 |
| 500 | 1 | 0.274 |
| 1000 | 1 | 0.198 |
| 2000 | 1 | 0.12 |
| 3000 | 1 | 0.088 |
| 4000 | 1 | 0.072 |
| 5000 | 1 | 0.066 |
| 10000 | 1 | 0.048 |

# RLC Bandpass Filter

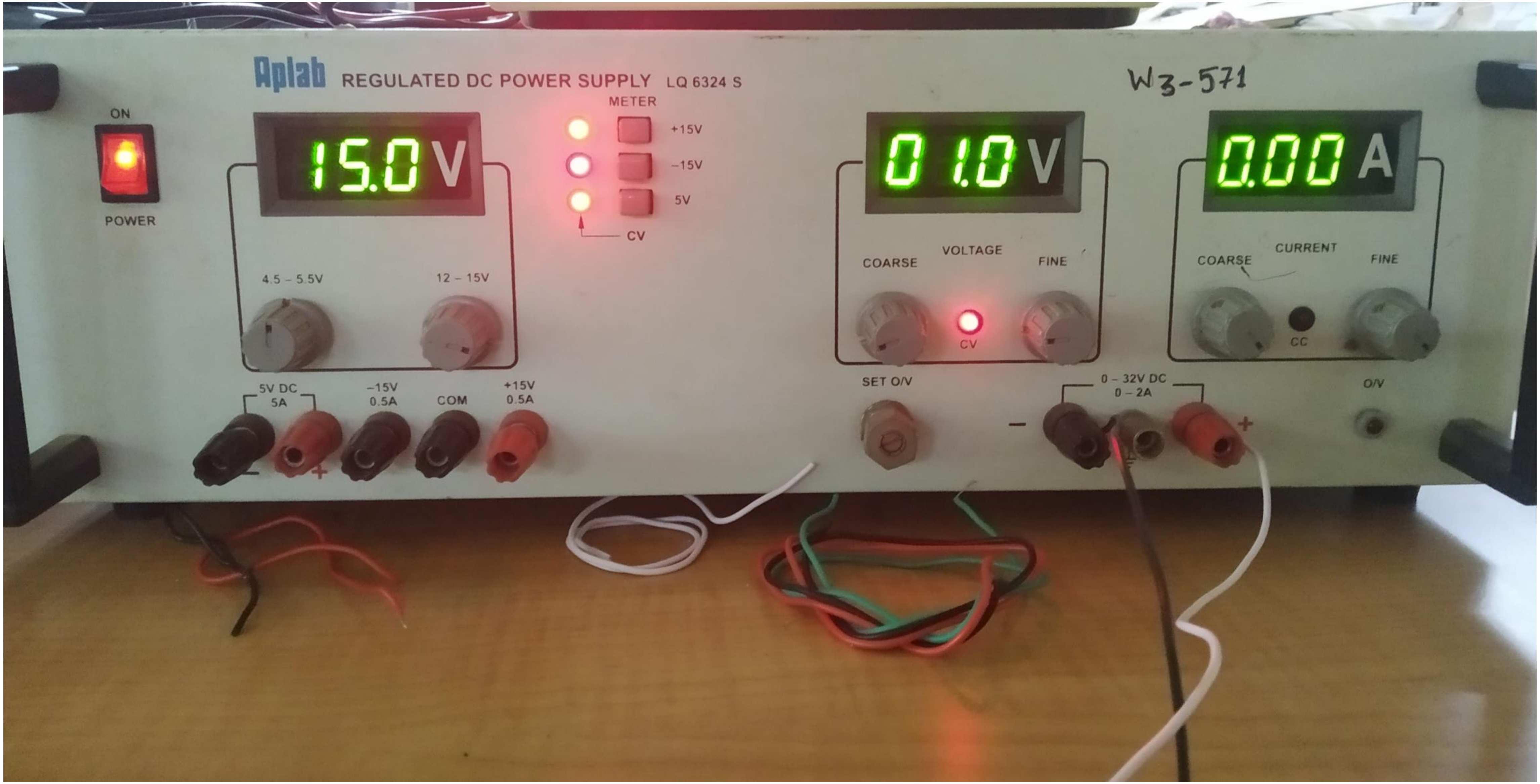


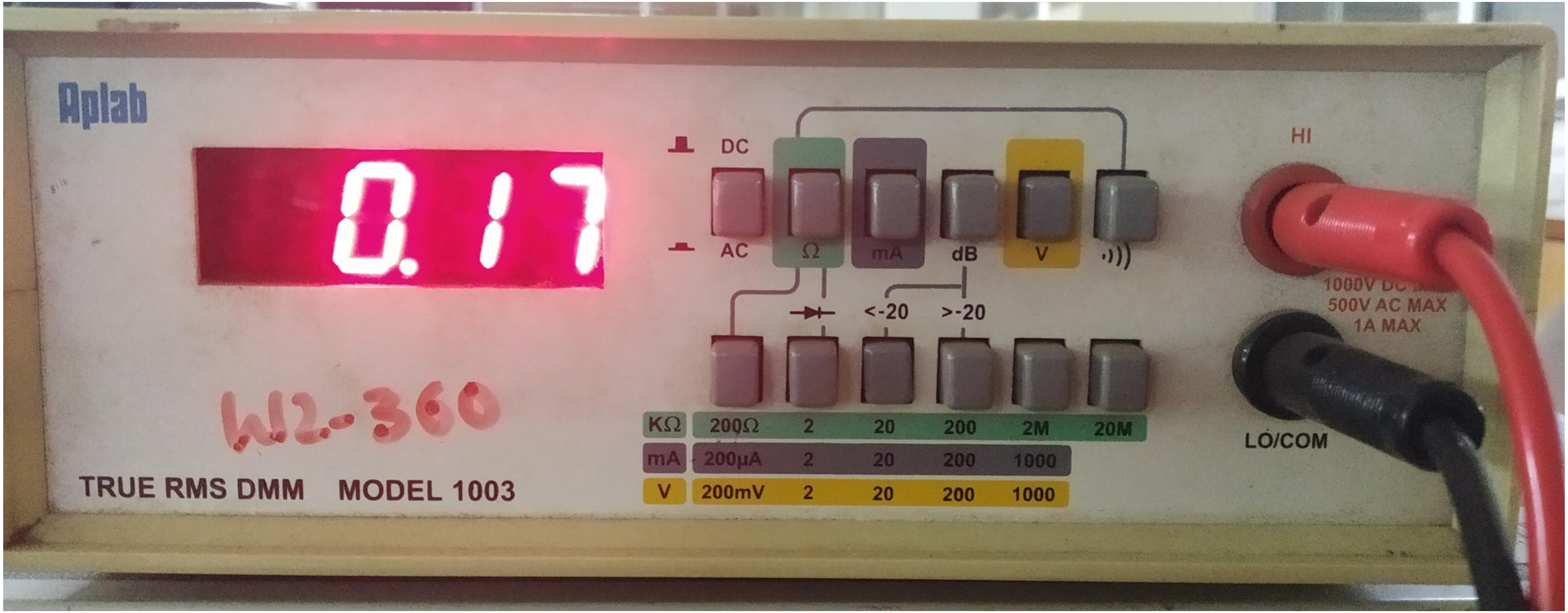

- R = 1 kΩ, L = 10 mH and C = 0.1 μF

- Will share the measured results later.

# Lab Equipment

- DC Power Supply (Aplab)
- DMM (Aplab)
- DSO (Tektronix)
- AFG (Tektronix)


Aplab
REGULATED DC POWER SUPPLY LQ 6324 S
W3-571
ON
POWER
15.0 V
METER
+15V
-15V
5V
CV
4.5 - 5.5V
12 - 15V
01.0 V
VOLTAGE
COARSE
FINE
CV
0.00 A
CURRENT
COARSE
FINE
CC
5V DC
5A
-15V
0.5A
COM
+15V
0.5A
SET O/V
0 - 32V DC
0 - 2A
O/V


Aplab
0.17
DC
AC
Ω
mA
dB
V
<-20
>-20
HI
1000V DC
500V AC MAX
1A MAX
LO/COM
W2-360
KΩ 200Ω 2 20 200 2M 20M
mA 200μA 2 20 200 1000
V 200mV 2 20 200 1000
TRUE RMS DMM MODEL 1003


Tektronix TDS 1002B TWO CHANNEL DIGITAL STORAGE OSCILLOSCOPE
60 MHz 1 GS/s
Restart
AUTORANGE
SAVE/RECALL
MEASURE
ACQUIRE
HELP
AUTOSET
REF MENU
UTILITY
CURSOR
DISPLAY
DEFAULT SETUP
SINGLE SEQ
RUN/STOP
SAVE
PRINT
VERTICAL
POSITION
HORIZONTAL
POSITION
TRIGGER
LEVEL
HORIZ MENU
TRIG MENU
CH 1 MENU
MATH MENU
CH 2 MENU
SET TO ZERO
SET TO 50%
VOLTS/DIV
SEC/DIV
FORCE TRIG
TRIG VIEW
PROBE CHECK
CH 1
CH 2
EXT TRIG
300V CAT II
USB Flash Drive
PROBE COMP ~5V@1kHz

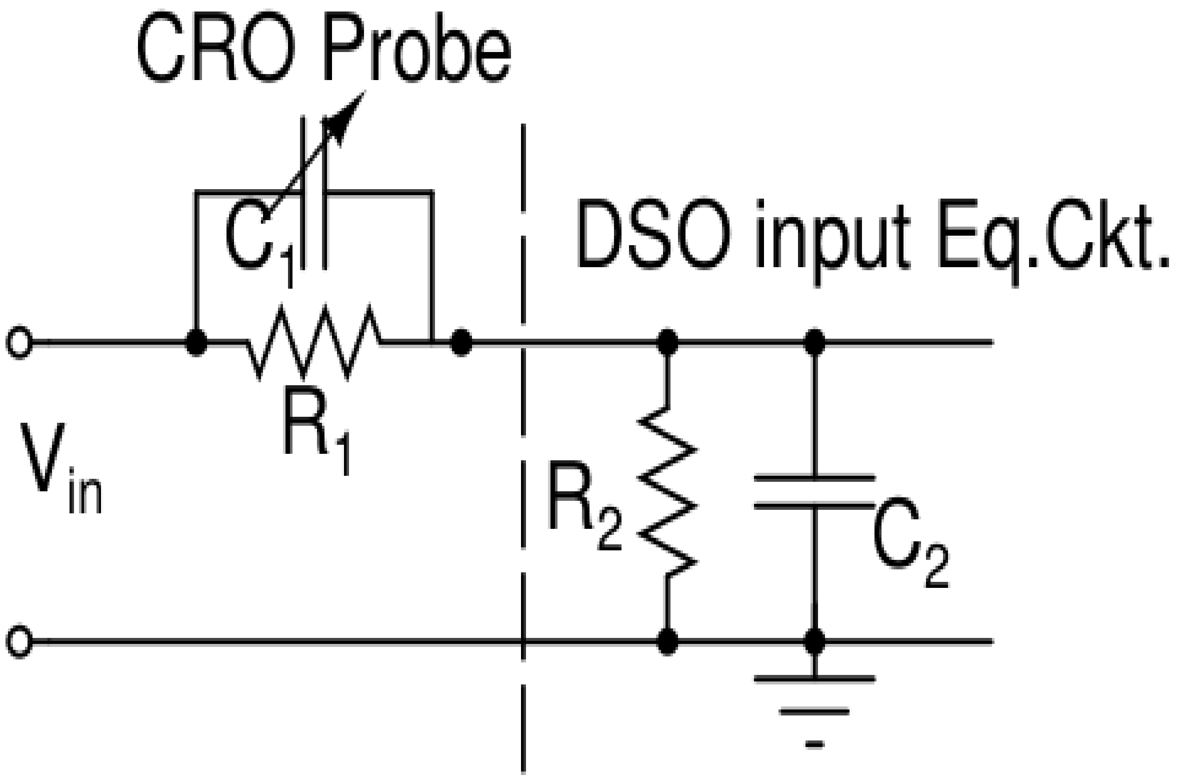
- CRO Probes, 1X/10X facility

- Locate the Adjustable Capacitor

&

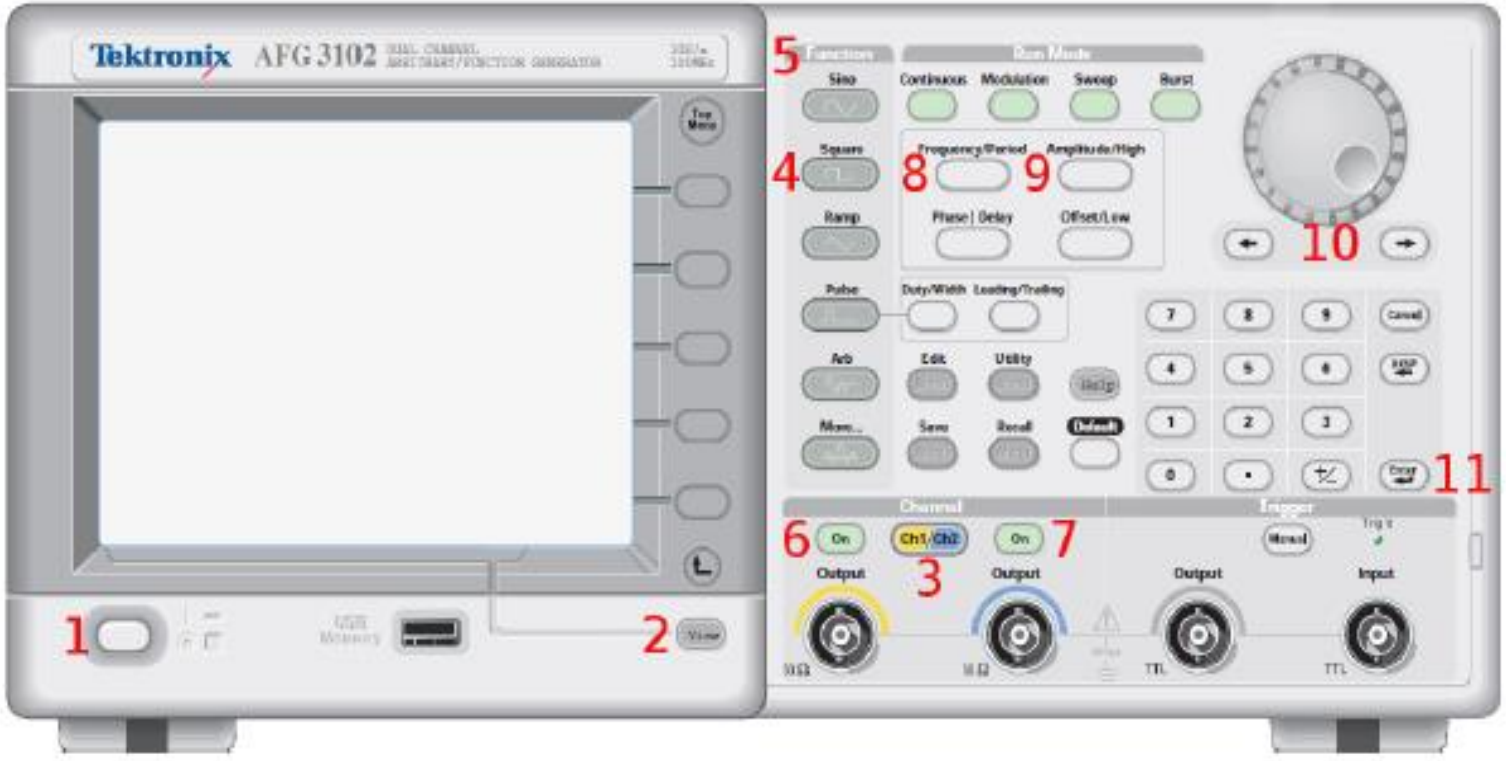
- 1X/10X switch

# CRO Probes




- CRO/DSO input resistance = 1 Mohm
- Input capacitance = 10 to 20 pF (typ)
- High RC time constant
  - Pulse Measurements can go very wrong
- CRO Probes ('Compensated Attenuators')
  - Cancel the input capacitance by adding and adjusting another capacitor in series

# Arbitrary Function Generator




- All types of Waveforms
- Can set Amplitudes and offset
- Can choose output Load