Electronics Lab

This document contains two sample lab reports.

The instructions that were followed by the students have since been updated, so that your report may require a few different items.

1. Scanned image of a lab report for Lab #1.

This paper was one of the best in the class in its year, although it is not as easy to read as the next example.

2. Scanned image of a lab report for Lab #2.

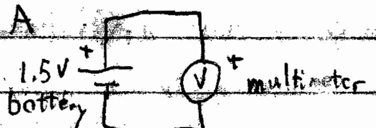
This is a perfect lab report for Lab #2. In addition to having perfect content, it is also very easy to read.

029:128

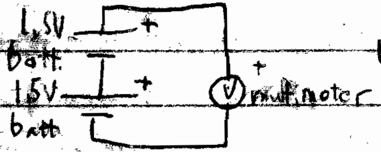
Laboratory Report 1

Preface: This report serves as a summary of the basic procedures the student carried out to familiarize himself with common electronic laboratory equipment, simple circuits, error analysis, and basic circuit concepts.

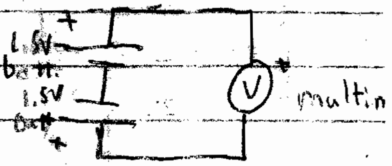
Section 1, part A



single battery circuit



2 batteries in series, forward polarity



2 batteries in Series, reverse polarity

instruments used: BK Model 388-HD multimeter

Voltage across the multimeter was measured for each circuit shown. The number of batteries & their relative orientations were varied. Errors were estimated based on the specifications given in the lab manual (Goree, vii).

$V_{batt1} = 1.561\,V \pm 8.8\times10^{-3}\,V$ $\quad V_{batt2} = 1.565\,V \pm 8.8\times10^{-3}\,V$

$V_{12f} = 3.11\,V \pm 0.026\,V$ $\quad V_{12r} = 0.047\,V \pm 1.2\times10^{-3}\,V$

$V_{fcalc} = 3.126\,V \pm 1.24\times10^{-2}\,V$ $\quad V_{rcalc} = 4\times10^{-3}\,V \pm 1.24\times10^{-2}\,V$

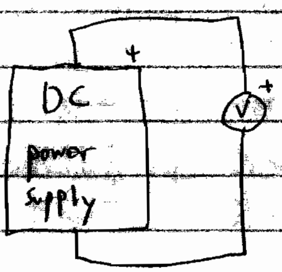
prop. of errors

$$V_{calc} = V_1 \pm V_2 \rightarrow \Delta V_{calc}^2 = \left(\frac{dV_c}{dV_1}\Delta V_1\right)^2 + \left(\frac{dV_c}{dV_2}\Delta V_2\right)^2 = (\Delta V_1)^2 + (\pm\Delta V_2)^2 = \Delta V_1^2 + \Delta V_2^2$$

$$\Delta V_c = \sqrt{(8.8\times10^{-3}\,V)^2 \cdot 2} = \boxed{1.24\times10^{-2}\,V}$$

The error ranges of V_{12f} and V_{fcalc} overlap, as do the error ranges of V_{12r} and V_{rcalc}, indicating these experimental values agree with theoretical calculation.

Part B



Two voltages produced by the power supply were measured. Voltage put out by the power supply was varied. Errors were estimated as in part A (Goree, vii) for multimeter and estimated at ±1 V for the eye for DC power supply.

a little high, although this would include instrument unc

the eye can tell from ±.1 to ±.5 un

Instruments Used: BK model 388-HD multimeter
HP 721 A DC supply

according to multimeter

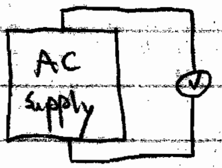
$V_{1m} = 50.8\ V \pm 0.354\ V$ $V_2 = 80.5\ V \pm 0.0503\ V$

according to DC supply

$V_1 = 50\ V \pm 1\ V$ $V_2 = 80\ V \pm 1\ V$

The error bars for both V_1 measurements overlap, as do those for the V_2 measurements, indicating that both measurements are resonable.

Part 2



RMS voltage output and frequency of the AC source were measured. Nothing was varied. No errors were estimated.

Equipment used: Custom built AC supply, BK Model 388 HD Multimeter

$V_{ac\,rms} = 8.14\ V$ $f = 60\ Hz$

(8 V expected) (60 Hz expected)

Part 3, part A

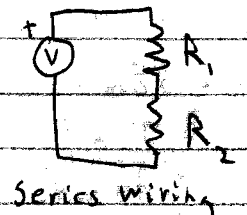
The resistances of 10 resistors were measured & compared to the value of resistance recorded on the resistor. Only resistance was varied. Errors were calculated as in a (Gurer, Vii)

Instruments used: BK Model 388HD Multimeter

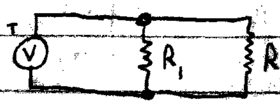
	Color Code	Nominal Value (Ω)	Tolerance	Measured Value (Ω)	Multimeter Scale	Mult err (Ω)	error fraction
*	Yel Blu Org Sil	46×10^3	10%	48.8×10^3	200K	±466	0.00954
*	Grn Red Org Sil	82×10^3	10%	85.7×10^3	200K	±743	0.00867
*	Grn Blu Red Sil	56×10^2	10%	57.3×10^2	20K	±53	0.0093
	Grn Blk Yel Sil	50×10^4	10%	55.8×10^4	2M	±5185	0.00929
*	Brn Red Red Gol	12×10^2	5%	1.274×10^3	2K	±10.6	0.00832
	Brn Blu Red Gol	16×10^2	5%	1.799×10^3	2K	±14.5	0.00806
	Grn Brn Blk Gol	51×10^0	5%	54.1	200	±0.506	0.00935
	Brn Grn Blk Gol	15×10^0	5%	18.8	200	±0.241	0.0128
*	Brn Grn Org Gol	15×10^3	5%	14.34×10^3	20K	±118	0.00823
*	Brn Red Org Sil	12×10^3	10%	12.49×10^3	20K	±104	0.00833

* falls within specified tolerance

Part B



series wiring



parallel wiring

Resistance across the shown circuit setup was measured. Only circuit layout was varied. Errors were calculated as before in 1a (Goree, vii).

Equipment used: BK Model 388HD Multimeter

$R_1 = 48.8\times10^3\,\Omega \pm 466\,\Omega$ $\qquad R_{series(m)} = 63.1\times10^3\,\Omega \pm 570\,\Omega$

$R_2 = 14.34\times10^3\,\Omega \pm 118\,\Omega$ $\qquad R_{par(m)} = 11.0\times10^3\,\Omega \pm 180\,\Omega$

$R_{series(calc)} = R_1 + R_2 = 63.14\times10^3\,\Omega \pm 570\,\Omega$

$\Delta R^2 = (\Delta R_1)^2 + (\Delta R_2)^2 = (466\,\Omega)^2 + (118\,\Omega^2) = (570\,\Omega)^2$

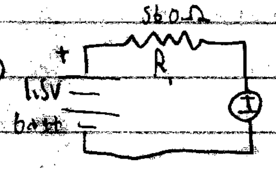
$R_{parallel(calc)} = (R_1^{-1} + R_2^{-1})^{-1} = 11.08\times10^3\,\Omega \pm 2.90\,\Omega$

$\Delta R^2 = \left(\frac{dR}{dR_1}\Delta R_1\right)^2 + \left(\frac{dR}{dR_2}\Delta R_2\right)^2$ $\qquad \frac{dR}{dR_1} = -1(R_1^{-1}+R_2^{-1})^{-2}\cdot -1R_1^{-2} = \frac{1}{(R_1^{-1}+R_2^{-1})R} \rightarrow 1.65\times10$

$\Delta R = \sqrt{(4.65\times10^{-5}\cdot 48.8\times10^3)^2 + (5.39\times10^{-5}\cdot 14.34\times10^3)}$ $\qquad \frac{dR}{dR_2} = \frac{\text{[illegible]}}{(R_1^{-1}+R_2^{-1})R_2^2} = 5.39\times10^{-5}\,\Omega^{-1}$

$\Delta R = 2.90\,\Omega$

Part 5



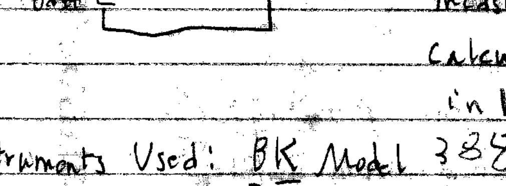
The value of R_1 was measured, and then current was measured directly through the circuit as well as being calculated. Nothing was varried. Errors were measured as in 1a (Goree, vii)

Instruments Used: BK Model 388 HD Multimeter

$R_{1m} = 559\,\Omega \pm 5.19\,\Omega$ $\qquad I_m = 2.7\,mA \pm 0.127\,mA$

$\frac{V}{R} = I_{calc} = 2.68\,mA$, This calculated value is within the error bars of the measured value for I, indicating experimental value matches prediction.

Part 6



Voltage across load was measured as well as current in circuit. Load Resistance was varied. Error was calculated as in 1a (Goree, vii).

Instruments used: BK Model 388HD Multimeter, General Radio Co 1432-S Decade Resistor

(kΩ) load Resistor	Current	Voltage across load
0.3	0.421mA ± 0.00521mA	132mV ± 1.66mV
0.7	0.380mA ± 0.00480mA	276mV ± 2.38mV
1.5	0.318mA ± 0.00418mA	491mV ± 3.46mV
3	0.243mA ± 0.00343mA	748mV ± 4.74mV
4.5	0.197mA ± 0.00297mA	906mV ± 5.53mV
6	0.166mA ± 0.00266mA	1013mV ± 6.065mV

a. In this case, measuring current will be more accurate, since measuring voltage + calculating current flow will result in the propagation of errors, since resistance also has an error value associated with it. It's actually not that trivial.

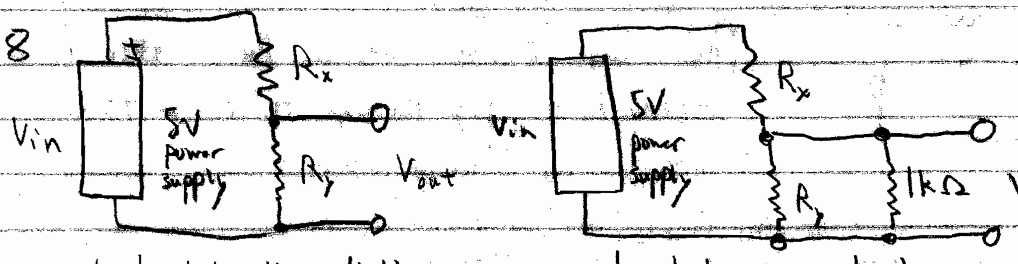
b. please see attached graph.

c. $I_{ideal} = \frac{V}{R} = \frac{1.5V}{3.27\times10^{3}\Omega} = 0.459mA \times 90\% = 0.413mA$

from graph, 90% cutoff ≈ 0.4kΩ

Instruments Used
Heathkit 5V power supply
BK Model 388 HD Multimeter
General Radio Co. 1432-S Decade Resistor

Part 8



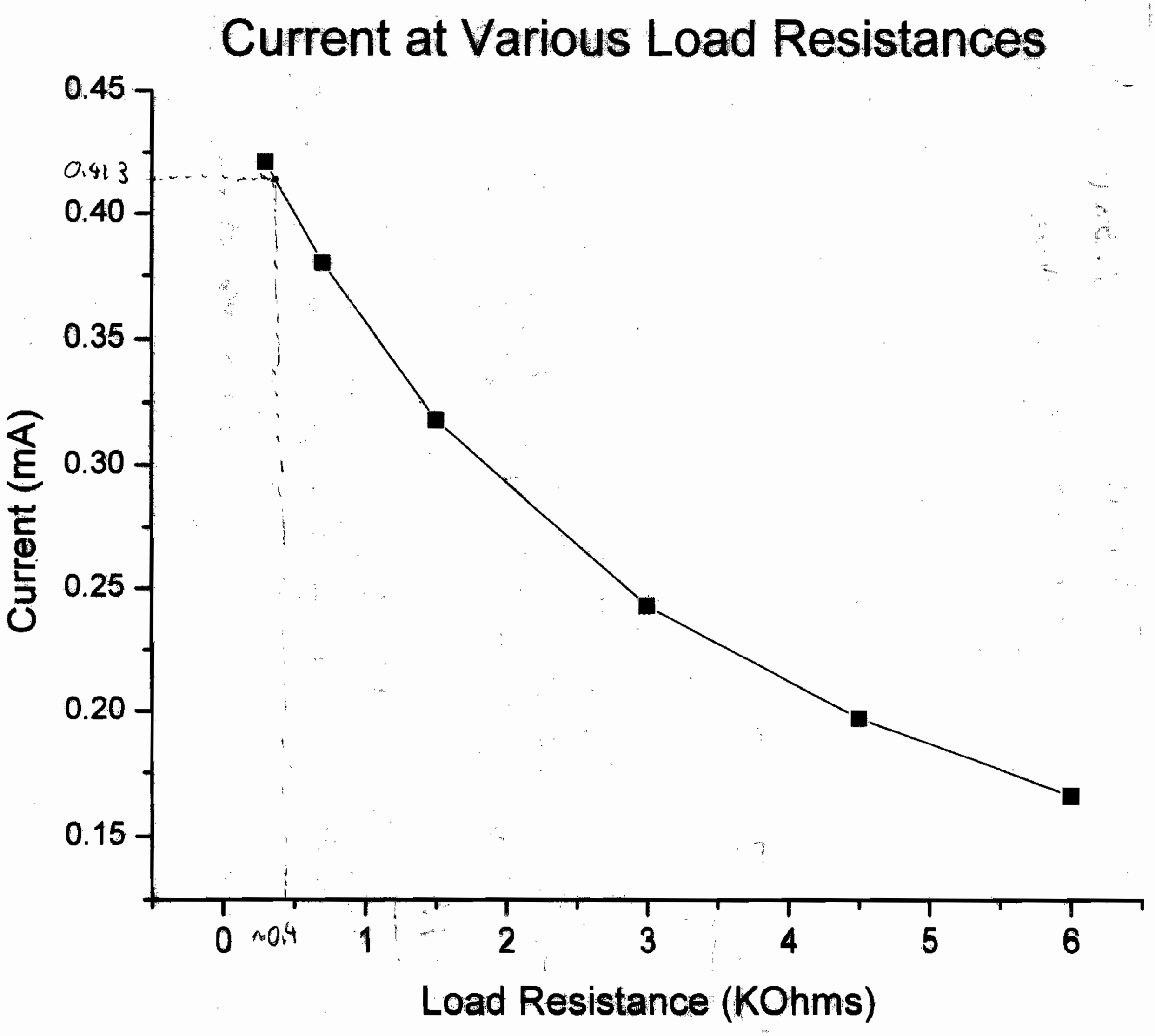
unloaded voltage divider

loaded voltage divider

Input + Output Voltage were measured for the above circuits. The resistances R_x + R_y were varied. No errors were calculated.

unloaded		loaded	
$R_x = 3.27k\Omega$	$R_x = 1.60k\Omega$	$R_x = 3.27k\Omega$	$R_x = 1.60k\Omega$
$R_y = 1.60k\Omega$	$R_y = 3.27k\Omega$	$R_y = 1.60k\Omega$	$R_y = 3.27k\Omega$
$V_{in} = 4.92V$	$V_{in} = 4.96V$	$V_{in} = 4.92V$	$V_{in} = 4.96V$
$V_{out} = 3.344V$	$V_{out} = 1.634V$	$V_{out} = 0.788V$	$V_{out} = 1.628V$
$V_{out}/V_{in} = 0.679$	$V_{out}/V_{in} = 0.329$	$\frac{V_{out}}{V_{out\,unloaded}} \times 100\% = 48.2\%$	$\frac{V_{out}}{V_{out\,unloaded}} = 48$[illegible]%
$V_{out}/V_{in(calc)} = \frac{R_x}{R_x+R_y} = \frac{3.27k\Omega}{4.87k\Omega} = 0.671$	$V_{out}/V_{in(calc)} = 0.328$	theorized value of above ratio: see back of attached graph (#1)	theoretical value of above ratio: see back of attached graph (#2)

Both experimental values ~~are~~ within 2 sig figs of the calculated values.


Current at Various Load Resistances
Current (mA)
0.45
0.413
0.40
0.35
0.30
0.25
0.20
0.15
0
~0.4
1
2
3
4
5
6
Load Resistance (KOhms)

1.

$$R_{eq} = \frac{1}{\frac{1}{R_y} + 1\times10^{-3}} = \text{[illegible]}$$

$$\frac{V_{out}}{V_{in}} = \frac{\text{[illegible]}}{R_x + R_{eq}} \rightarrow V_{out} = \frac{R_{eq} V_{in}}{R_x + R_{eq}} = \frac{615\,\Omega \cdot 4.92\,V}{(615 + 3270)\,\Omega} = 0.779\,V$$

$$\frac{0.779\,V}{\text{[illegible]}} \times 100\% = 47.7\%$$

↳ This value is comprable to the experimental ratio, suggesti (48.2%) that the calculation + measurement reinforce one another.

2. $$R_{eq} = \frac{1}{\frac{1}{3.27\,k\Omega} + \frac{1}{1000\,\Omega}} = 766\,\Omega$$

$$V_{out} = \frac{R_{eq} V_{in}}{R_x + R_{eq}} = \frac{766\,\Omega \cdot 4.96\,V}{(766\,\Omega + 1660\,\Omega)} = 1.57\,V$$

$$\frac{1.57\,V}{3.34\,V} \times 100\% = 47.0\%$$

↳ this value is comprable to the experimental ratio, (48.6%) suggesting that the calc + measurement reinforce one another.

Electronics Lab

This is a sample lab report for Lab #2.

The instructions that were followed by the student here have since been updated, so that your report may require a few different items.

Lab 2: AC Measurement

100

Preface

- Measure AC signal (amplitude, frequency, phase) using oscilloscope
- Study RC circuits

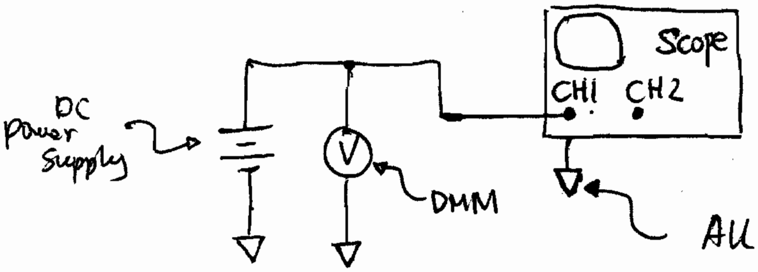
Experiment

1. Measurement of Voltages

(a) DC voltage

Apparatus: oscilloscope, digital multimeter, power supply

Procedure: set up scope;
set output voltage of power supply;
measure the output voltage using the scope & the multimeter.



All grounds are connected physically.

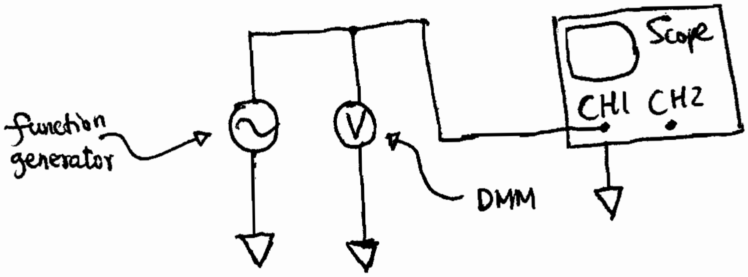
Voltage set by power supply	voltage measured by multimeter	scale of multimeter	Voltage measured by scope	scale c scope
(1 ± 0.25)V	(1.252 ± 0.007)V	4V	(1.25±0.05)V	0.5V/Di
(2 ± 0.25)V	(2.322 ± 0.013)V	4V	(2.35±0.05)V	0.5V/Div
(3 ± 0.25)V	(3.260 ± 0.017)V	4V	(3.30±0.05)V	0.5V/Div
half the minimum scale, i.e. $\frac{1}{2}$ x0.5V	according to DMM's specification		half minimum division multiplied by scale, i.e 0.1 div x0.5 V/Div	

The meter is more precise than oscilloscope, although the precision of oscilloscope's measurement can be improved by choosing smaller scale for verticle display.

(b) AC Voltages

Apparatus: oscilloscope, digital multimeter function generator

procedure: connect circuit;
set up function generator;
measure RMS voltage using multimeter & peak-to-peak voltage using scope.



Results:

$V_{RMS} = (342.4 \pm 1.8)\ mV \rightarrow \left(\frac{\delta V}{V}\right)_{DMM} = 0.5\ \%$
by DMM
400 mV scale

✓

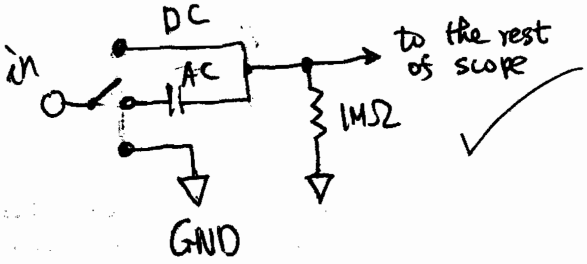
$V_{\text{peak-to-peak}} = (1.00 \pm 0.02)\ V$
by scope
0.2 V/Div

$\div 2\sqrt{2}$ $\div 2\sqrt{2}$

$V_{RMS} = (0.35 \pm 0.01)\ V \rightarrow \left(\frac{\delta V}{V}\right)_{scope} = 2.9\ \%$
calculated using $V_{\text{peak-to-peak}}$

The meter is more precise, as seen from $\left(\frac{\delta V}{V}\right)_{scope} > \left(\frac{\delta V}{V}\right)_{DMM}$

(c) AC & DC coupling



✓

Difference: using DC coupling, one can see a verticle deflection of the trace when changing the offset; For AC coupling, there is no response to DC offset.
When using AC coupling, the signal passes a capacitor, which blocks the DC offse

2. Measurement of frequency

Apparatus: oscilloscope, digital multimeter, function generator

procedure: prepare the circuit as in 1(b) & (c);
measure frequency using multimeter;
measure time per cycle using scope & calculate frequency.

Frequency by multimeter	uncertainty in DMM measurement	Frequency by scope	uncertainty in scope measurement
10.25 kHz	0.13 kHz	10309 Hz (using 10 us/Div)	103 Hz using $\left\|\frac{\delta \overset{\text{frequenc}}{f}}{f}\right\| = \left\|\frac{\delta T}{T}\right\|$ $\|\delta f\| = \left\|f\frac{\delta T}{\underset{\text{period}}{T}}\right\|$

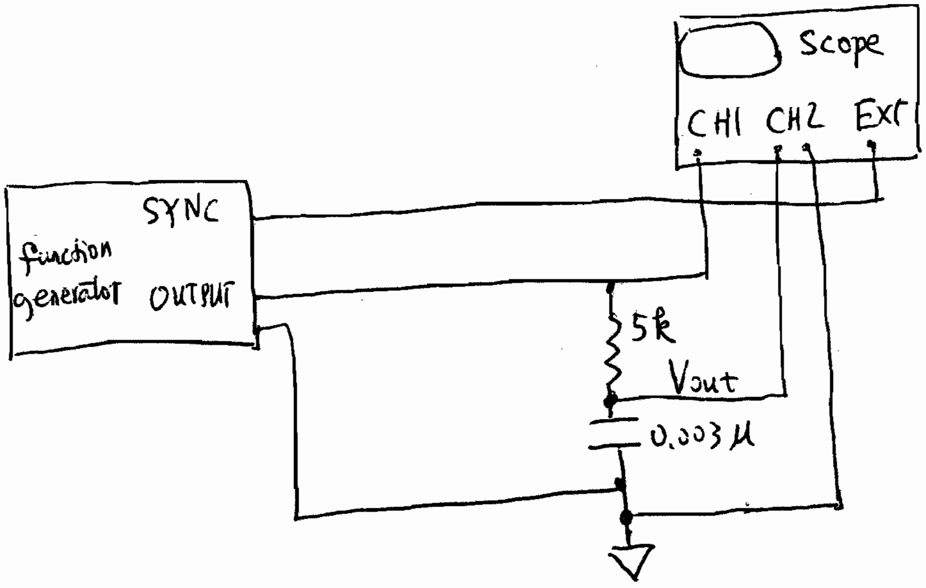
✓

3. Time constant of an R-C circuit

Apparatus: osilloscope, digital multimeter,
function generator, 5kΩ resistor,
0.003 μF capacitor

Procedure:

Connect circuit
set function generator & the scope
measure charging & discharging times



Results:

$R = 5.60\ k\Omega \pm 0.04\ k\Omega$

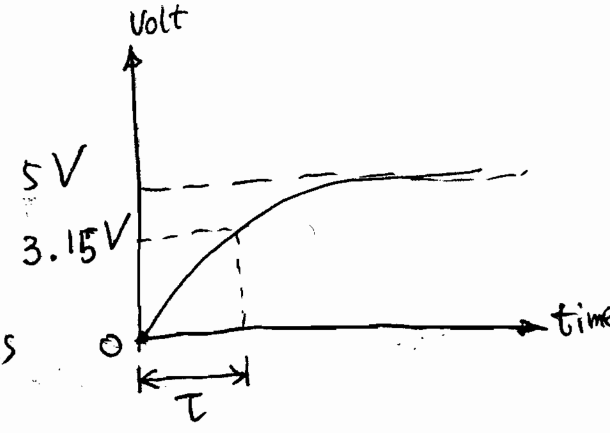
$C = 3.50\ nF \pm 0.11\ nF$

(a) Charging time

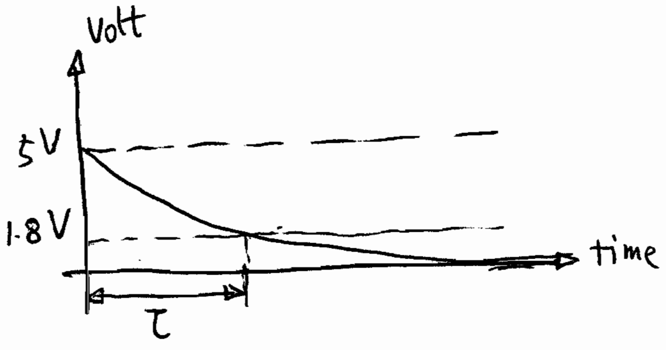
$\tau^{charge}_{measure}$ by scope 10 μs/Div $= (2.0 \pm 0.1) \times 10\ \mu s$

$= 20.0\ \mu s \pm 1.0\ \mu s$

$$\frac{\tau^{charge}_{measure}}{RC} = 1.02$$



(b) Discharging time

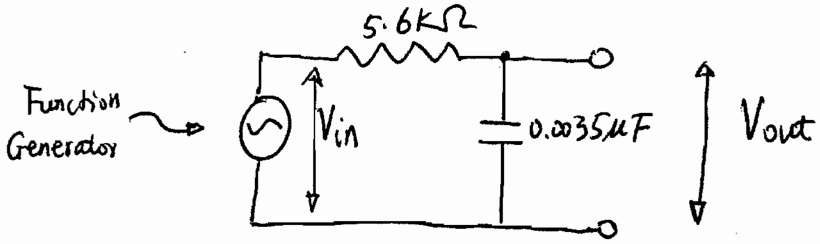


$\tau^{\text{discharge}}_{\text{measure}}$ by Scope 10us/Div $= (1.85 \pm 0.1) \times 10\mu s/\text{Div}$

$= 18.5\,us \pm 1.0\,\mu s$

$$\frac{\tau^{\text{discharge}}_{\text{measure}}}{RC} = 0.94$$

4. R-C Low-Pass Filter



Apparatus: same as 3

Procedure:

connect circuit as in 3
set function generator & scope
measure Vout & Vin at various frequencies.
measure time delay τ between Vout & Vin.

Results:

(a) Amplitude response

(i) see next page.

(ii) see next page.

(iii) The frequency at $\frac{V_{out}}{V_{in}} = 0.707$ is

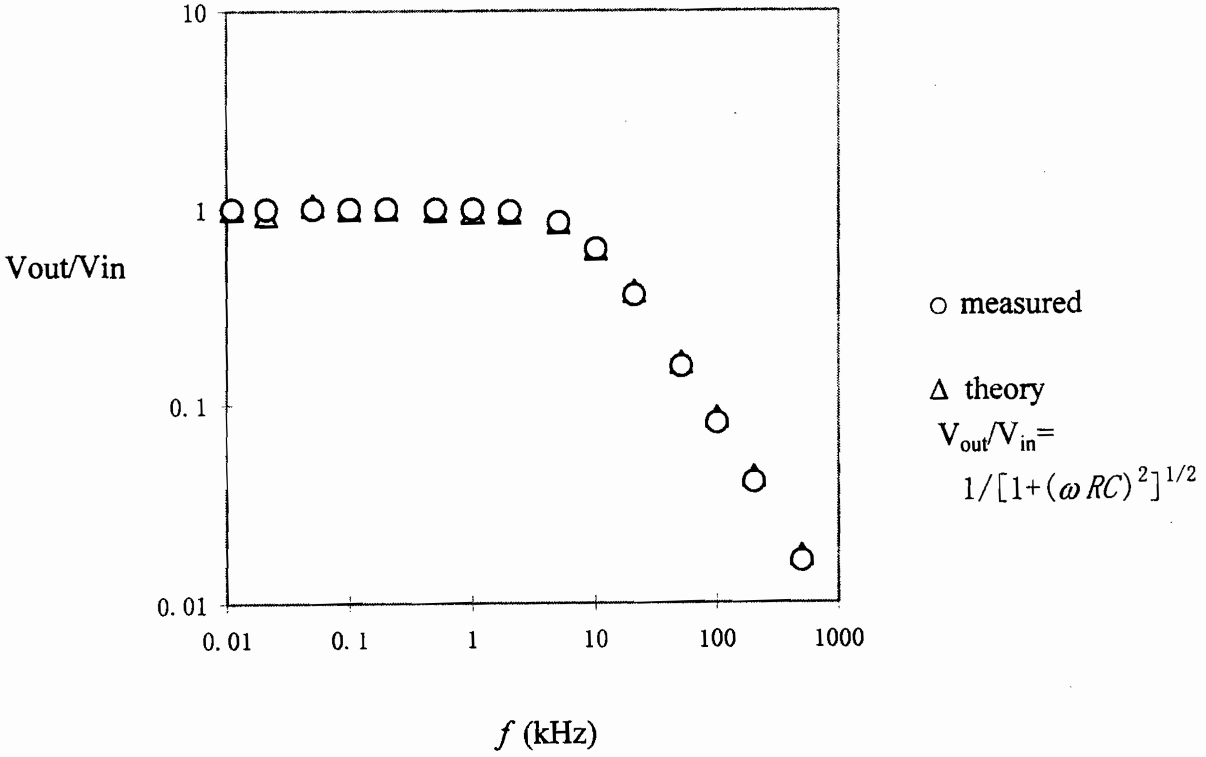
$$\left.\begin{array}{l} f_{\text{measure}} = (8.32 \pm 0.11)\ \text{kHz} \\ f_{\text{calculat}} = \frac{1}{\quad} = 8.12\ \text{kHz} \end{array}\right\} \Rightarrow \frac{f_{\text{measure}}}{f_{\text{calculat}}} = 1.02$$

R= 5.60 kΩ ± 0.04 kΩ
C= 3.50 nF ± 0.11 nF

f (Hz)	δf	Vin	δVin	Vout	δVout	Vout/Vin (measure)	Vout/Vin (theory)
0.011	0.001	4.8	0.1	4.8	0.1	1.0	1.00
0.021	0.001	4.9	0.1	4.6	0.1	0.9	1.00
0.05	0.002	4.8	0.1	5.0	0.2	1.0	1.00
0.1	0.002	5.0	0.1	5.0	0.2	1.0	1.00
0.201	0.003	5.0	0.1	5.0	0.2	1.0	1.00
0.501	0.006	5.1	0.1	5.0	0.2	1.0	1.00
1.001	0.011	5.1	0.1	4.9	0.1	1.0	0.99
1.999	0.021	5.1	0.1	4.9	0.1	1.0	0.97
5.02	0.06	5.0	0.1	4.3	0.1	0.9	0.85
10.09	0.11	5.1	0.1	3.2	0.1	0.6	0.63
20.7	0.3	5.1	0.1	1.95	0.02	0.4	0.37
50.8	0.6	5.0	0.1	0.82	0.02	0.2	0.16
100.1	1.1	5.1	0.1	0.44	0.02	0.1	0.08
200.1	2.1	5.1	0.1	0.22	0.01	0.0	0.04
500.0	5.1	5.0	0.1	0.086	0.002	0.0	0.02

δ*A* = uncrtainty in *A*

spelling



Amplitude Response of A Low-Pass Filter

(b) Phase Response

(i) see next page

(ii) see next page

(iii) The phase angle at $f = \frac{1}{2\pi RC}$:

$f = 8.1$ kHz

$\theta_{measure} = 43.15^\circ \pm 0.93^\circ$

$$\theta_{theory} = \arctan \omega RC$$

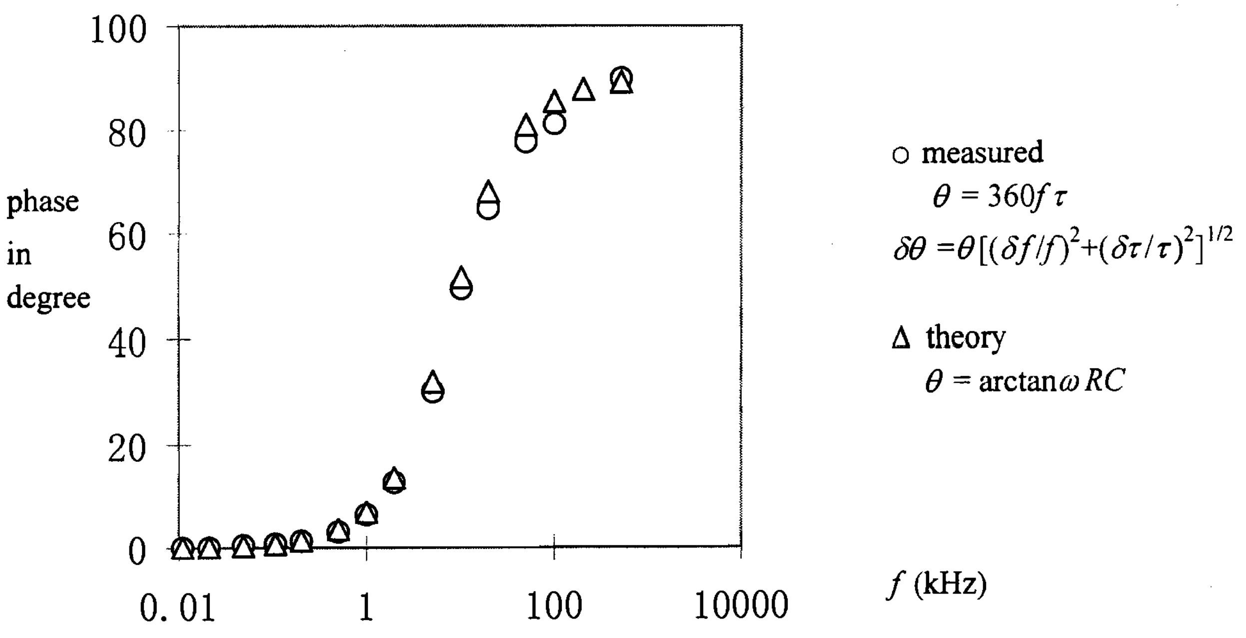
$$= \arctan(2\pi f \cdot RC)$$

$$= 45^\circ$$

R= 5.60 kΩ ± 0.04 kΩ

C= 3.50 nF ± 0.11 nF

f(kHz)	δf (kHz)	delay in msec (τ)	$\delta\tau$ msec	phase in degrees θ (measure)	$\delta\theta$ degree	phase in degrees (theory)
0.011	0.003	0.0000	0.0001	0.000	0.000	0.078
0.021	0.003	0.0000	0.0001	0.000	0.000	0.148
0.049	0.003	0.030	0.005	0.529	0.096	0.346
0.108	0.004	0.020	0.005	0.778	0.197	0.762
0.204	0.005	0.018	0.002	1.322	0.150	1.439
0.502	0.008	0.018	0.001	3.253	0.188	3.538
1.001	0.013	0.0180	0.0005	6.486	0.199	7.028
1.962	0.023	0.0180	0.0005	12.714	0.382	13.584
5.08	0.08	0.0165	0.0005	30.18	1.03	32.033
10.26	0.13	0.0134	0.0002	49.49	0.98	51.653
20.01	0.23	0.0090	0.0002	64.83	1.62	67.937
50.1	0.8	0.0043	0.0001	77.6	2.2	80.830
100.1	1.3	0.00225	0.00005	81.1	2.1	85.403
202.0	2.3	0.00144	0.00002	104.7	1.9	87.741
509.0	5.4	0.00049	0.00001	89.8	2.1	89.131



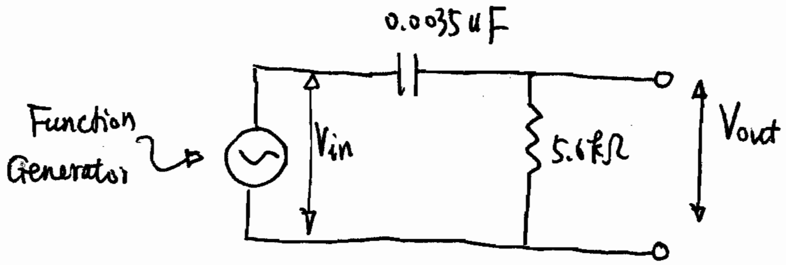
$\theta = 360 f\tau$

$\delta\theta = \theta[(\delta f/f)^2 + (\delta\tau/\tau)^2]^{1/2}$

$\theta = \arctan\omega RC$

Phase Response of A Low-Pass Filter

5. R-C High-Pass Filter



Apparatus : same as 3

Procedure :

connect circuit as above;
set function generator & scope
measure Vout & Vin at various frequencies

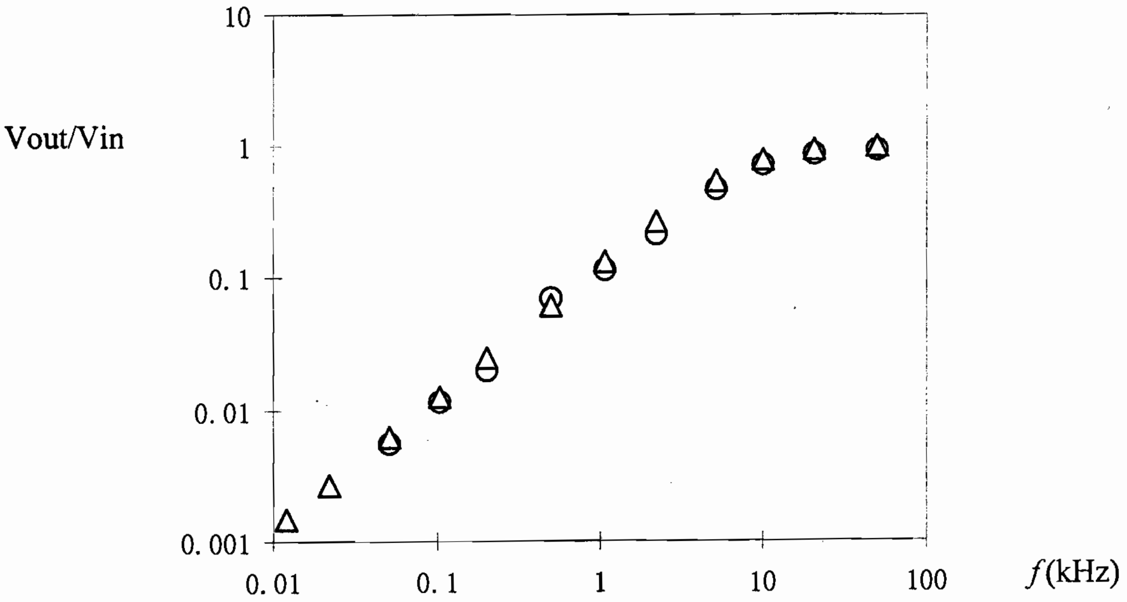
Results :

(i) See data table in the next page;
(ii) Amplitude response in the next page.

R= 5.60 kΩ ± 0.04 kΩ
C= 3.50 nF ± 0.11 nF

f (kHz)	δf	Vin	δVin	Vout	δVout	Vout/Vin (measure)	Vout/Vin (theory)
0.012	0.003	5.0	0.1	0.000	0.001	0.0	0.00
0.022	0.003	5.0	0.1	0.000	0.001	0.0	0.00
0.051	0.004	5.0	0.1	0.028	0.001	0.0	0.01
0.103	0.004	4.9	0.1	0.057	0.001	0.0	0.01
0.201	0.005	5.0	0.1	0.100	0.001	0.0	0.02
0.498	0.008	4.8	0.1	0.333	0.002	0.1	0.06
1.065	0.014	4.9	0.1	0.559	0.005	0.1	0.13
2.207	0.025	5.0	0.1	1.05	0.02	0.2	0.26
5.16	0.08	5.0	0.1	2.33	0.02	0.5	0.54
10.03	0.13	4.9	0.1	3.5	0.1	0.7	0.78
20.65	0.24	5.0	0.1	4.3	0.1	0.9	0.93
50.1	0.6	5.0	0.1	4.6	0.1	0.9	0.99

δA = uncrtainty in A;



○ measured

Δ theory

$$\mathrm{Vout/Vin} = \omega RC/[1+(\omega RC)^2]^{1/2}$$

High-Pass filter