

# Centralized Monitoring of AC Power Sources

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**Abstract-** Critical experiments such as the experiment conducted at CRL (Cosmic Ray Laboratory), Ooty which continuously monitors the cosmic shower requires an uninterrupted power supply. To suffice the requirement various power sources are used in parallel. Nearby lightning strikes or some other reasons, may cause a high voltage spike to occur at the output of these sources. A spike in the output of these power sources may result in adverse effects on the electronic circuit and eventually the experiment. It becomes essential to monitor the output of these sources in order to observe its effects on the experiment. This project aims at acquiring, storing, monitoring and displaying the current and voltage waveforms of different ac power sources along with the spikes and glitches on a centralized PC. It also displays various electrical parameters such as instantaneous peak voltage and current, RMS voltage and current, power, phase, etc. The current and voltage waveforms are logged in the PC along with real time.

**Keywords—** Gnuplot, transients, Hall Effect sensor

## I. INTRODUCTION

Nowadays along with AC mains UPS and diesel generators are commonly used as secondary power sources. Lightening, switches, abrupt changes in the load causes transients in the output of these sources. These transients affect the load or experiments driven by the sources. The equipment and devices used in industrial and commercial environment are more sensitive to power variations. Controls can be affected by temporary voltage dip or transients resulting in failure of important processes. A monitoring system is required to detect these transients. Conventional systems provide the electrical parameters but they generally don't have any provision to display the transients in the current or voltage waveform. Electrical parameters are calculated by averaging many cycles. Instantaneous values of voltage and current are lost in this case. They are unable to provide monitoring of voltage fluctuations or transients in the power sources. Beside this the conventional systems are costly. This project calculates instantaneous values of voltage and current. It displays the current and voltage waveforms on PC. Thus it becomes easy to see transients or other variation occurring in the power sources.

## II. DESIGN OF SYSTEM

### *Project Specifications:*

Input voltage = 240 V (RMS)

Frequency = 50Hz/60 Hz

Current = 55 A

Max. Transient frequency = 3.5 KHz

Max Transient amplitude = 500V

Parameters measured:  $V_{peak}$ ,  $I_{peak}$ ,  $V_{rms}$ ,  $I_{rms}$ , Phase difference, Power Factor, Form factor, True and Apparent power.

Communication Interface: USB

Display: Gnuplot on Linux

### *Block Diagram:*

The block diagram of the system is as shown in Fig. 1. It shows the basic building blocks of the system.

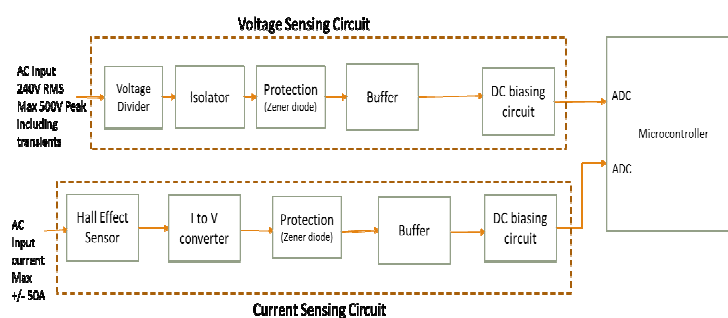


Fig. 1. Block diagram of voltage and current sensing circuit

### *Working:*

Output voltage of the power sources is stepped down by a high dividing factor using a resistive divider network. Hall Effect sensor is used to sense the current. The output of Hall Effect sensor is current and is converted to voltage using I to V

converter. Generally ADC does not acquire negative voltages. Hence the stepped down voltage and sensed current is given a DC shift so that the negative half of the cycle shifts above the ground potential. The shifted signal is given to internal ADC of microcontroller. The ADC samples are transferred to a centralized PC located away from sources using USB transmission protocol. The samples received at PC are logged in a text file. These samples are used to calculate the electrical parameters and also to plot the waveforms using Gnuplot. Both the operations are done in real time.

#### Design:

##### Circuit Diagram:

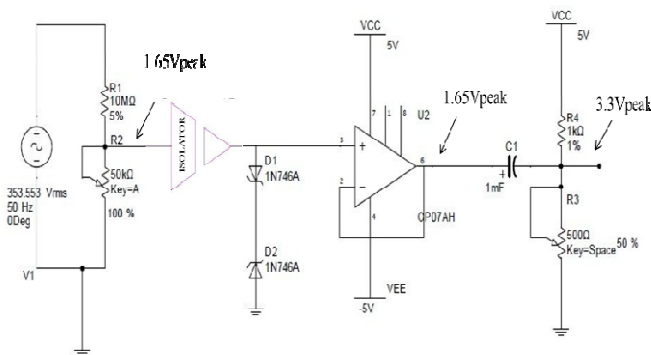


Fig. 2. Voltage sensing circuit.

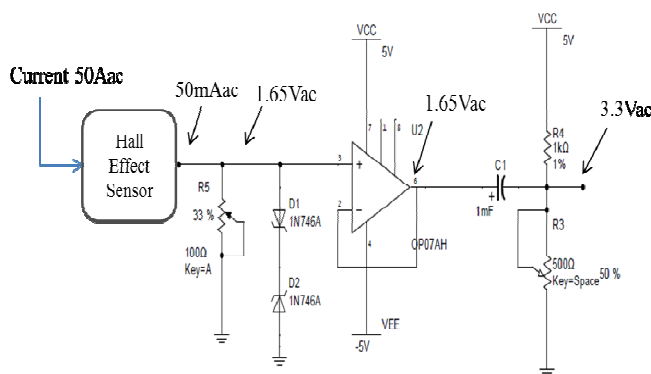


Fig. 3. Current sensing circuit.

#### 1. Voltage divider:

The high input voltage from the source must be stepped down to the acceptable range of ADC. For this purpose a simple voltage divider circuit can be used.

Max. Input voltage = 240 V (RMS)

Therefore  $V_{p-p} = 240 \times \sqrt{2} \times 2 = 678.72$  V

678.72 V + margin for transient (321.18 approx.) = 1000  $V_{p-p}$

Max input voltage to ADC = 3.3 V (considering PIC18F87J50)

$$\text{Dividing factor} = \frac{\text{Max input voltage}}{\text{Max input voltage to ADC}} = \frac{1000 \text{ V}}{3.3 \text{ V}} = 303.0303$$

Assume  $R1 = 10\text{M}\Omega$  .....To provide high input impedance

$$\text{Dividing factor (DF)} = \frac{R1 + R2}{R2}$$

$$303.0303 = \frac{10\text{M}\Omega + R2}{R2}$$

$$R2 = 33.109 \text{ K}\Omega$$

#### 2. Isolator:

The earth of AC and the ground of DC supply of the circuit are at different potentials. If they are connected a ground loop is formed. Thus an undesirable stray current flows between earth and ground. This introduce noise which may dominate the actual signal or may trip the supply. In worst case it may damage the circuit.

Another reason is that if the voltage divider fails then the entire input voltage may appear across the zener. This causes a large current to flow thereby damaging the zener and eventually damaging the entire circuit.

Under normal condition:

Isolator maximum Input voltage range = 3.3  $V_{p-p}$

Isolator maximum Input current = 36.55uA

Since gain of ISO122- P is unity,

Maximum isolator output voltage = 3.3 $V_{p-p}$

In worst condition (i.e. resistor divider network fails):

Isolator Input voltage range = 1000 $V_{p-p}$  max.

Isolator Input current = 19.3mA (If  $R1$  (10M $\Omega$ ) is short circuited)

Isolator Input current = 98uA (If  $R1$  (33K $\Omega$ ) is short circuited)

In this condition Isolator will saturate and give output voltage equal to saturation voltage which is 12.5 V.

#### 3. I to V converter:

It converts the current from the Hall Effect sensor to equivalent voltage. A simple resistor is used for this purpose

$$R = V/I$$

$$R = \frac{1.65}{50\text{mA}} = 33\Omega$$

#### 4. Protection (Zener Diode):

Max input voltage range of ADC for PIC18F87J50 is 0V to 3.3V. If the voltage exceeds this range then the ADC may get damage. Hence to prevent this we use back to back arrangement of zener diode which limits the positive as well as the negative voltage to 3.3V and -3.3V respectively.

Zener Breakdown voltage = 3.3V

Under normal condition:

Maximum input voltage to zener 1N746A = 3.3V

Maximum current supplied to Zener = 15mA

In worst condition (i.e. resistor divider network fails):

Input voltage to zener 1N746A = 12.5V max (saturation voltage of Isolator)

Input current supplied to Zener = 15mA max (Maximum source current from Isolator)

Breakdown voltage of Zener 1N746A = 3.3V max

Voltage drop across zener = 12.5V – 3.3V = 9.2V

Power dissipation = 9.2V x 15 mA = 187.5 mW

5. Buffer: If the output of the isolator is directly given to the DC biasing circuit then loading effect takes place. The resistance of both the circuits gets added. Low value of voltage is obtained as current is drawn from the isolator circuit. When a circuit has a very high input impedance, very small current is drawn and the voltage does not change. Hence a buffer circuit is used which has a high input impedance and low output impedance. This is nothing but impedance bridging.

For OP07 as buffer: Input Resistance = 60MΩ

6. DC biasing circuit:

DC biasing provides the required shift to the AC signal so as to shift the signal above ground potential.

Power supply to PIC18F87J50 = 3.3 V

Required DC shift  $V_{DC} = \frac{3.3}{2} = 1.65V$

$V_{CC} = 5V$

$V_{DC} = \left( \frac{R_3 + R_4}{R_3} \right) * V_{CC}$

$1.65V = \left( \frac{R_3}{1k\Omega + R_3} \right) * 5V$

$R_3 = 492.54\Omega$  .....A potentiometer is used to adjust the value precisely.

Coupling Capacitor:

The coupling capacitor at the output of buffer plays an important role in blocking the DC current flowing from DC biasing to buffer. The value of this capacitor is decided using the following formula:

$C = \frac{1}{2\pi F R}$  ..... (High pass RC filter)

Where, F = cutoff frequency.

Considering parallel combination of  $R_3$  and input impedance of ADC,

$R = 492 || 2.5k = 411 \Omega$

Thus,  $C = \frac{1}{2\pi * 50 * 411} = 7.74\mu F$

This value of capacitor gives 3dB attenuation at 50Hz. A capacitor with a larger value can be used to reduce the attenuation. Capacitor of 1000uF gives nearly 0dB attenuation at 50Hz.

Therefore,  $C = 1000\mu F$ .

7. Microcontroller:

PIC18F87J50 has 10 bit 12 channel ADC (SAR), USB V2.0 with speed of 1.5Mb/s, 3940 bytes of SRAM.

For 10 bit ADC,

Resolution(R) =  $\frac{V}{Q} = \frac{3.3V}{1024} = 3.222mV$

For 1000 V

Resolution = 3.222mV x dividing factor = 3.22mV x 303.0303 = 0.9765V

Thus for 1000V, resolution of ADC is nearly 1V

Acquisition Time:

$T_{OSC} = \frac{1}{F_{OSC}} = \frac{1}{1MHz}$

$T_{AD} = T_{OSC} * 8$   
 = 0.7uSec

$T_{ACQ} = 2.45uSec$  .....from Datasheet.

Thus,  $T_{ACQ} = 4 * T_{AD}$

### III. SOFTWARE ASPECTS

Gnuplot:

Gnuplot is a graphing program for Linux having a command line interface i.e. the command should be written in the gnuplot interface for performing the required operation. Gnuplot can be used to plot 2D or 3D graphs. In this project gnuplot is used to plot a 2D graph of voltage and current with respect to time. The data to be plotted should be written in a file. The data file should have data arranged in columns of numbers with each column separated by a tab or space.

Gnuplot uses various output terminals such as *wxt*, *png*, *svg*, *postscript*, *epslatex*, *jpeg*, etc. The terminal is set to *wxt* to generate output in separate terminals.

*Plot "datalog.txt" using 1:2* :- This commands plots the data from the file with 1<sup>st</sup> column on horizontal axis and 2<sup>nd</sup> column on vertical axis.

*Set xdata time* :- It is used tell gnuplot that the data on x axis is time.

*Set timefmt "%H:%M:%S"* :- To set the time format.

All these commands are stored in a character array. This character array is piped to the gnuplot interface from the C interface. For this purpose we open gnuplot process in persistent mode. It opens an interface that one can use to send commands as if they were typing into the gnuplot command line. The persistent mode keeps the plot open even after the C program ends.

#### IV. COMMUNICATION

USB:

To transfer the samples from microcontroller to PC, USB is used as a communication protocol.

There are four types of USB transfer namely:

1. Bulk transfer
2. Interrupt Transfer
3. Isochronous Transfer
4. Control Transfer

Out of these Bulk data transfer is used as it provides data integrity. It can transfer 1 byte to 2048 bytes at a time using bulk transfer. But as size of data packet increases from 1 byte to 2048 bytes, time required to transfer also increases from 0.1mS to 60mS. Delay of 60ms implies loss of three AC cycles. Hence maximum USB packet size is kept as four bytes. Four byte means 1 sample of voltage and 1 sample of current. This transfer size provides 200uS to 270uS transmission delay, which gives data rate of  $\frac{20mS}{200uS} = 100$

samples/cycle to  $\frac{20mS}{270uS} = 74$  samples/cycle respectively. At this rate we can measure the spike of  $\frac{1}{270uS} = 3.7KHz$  in a 50Hz cycle.

#### V. FLOWCHART

ig. 5. Flowchart for parameter calculation

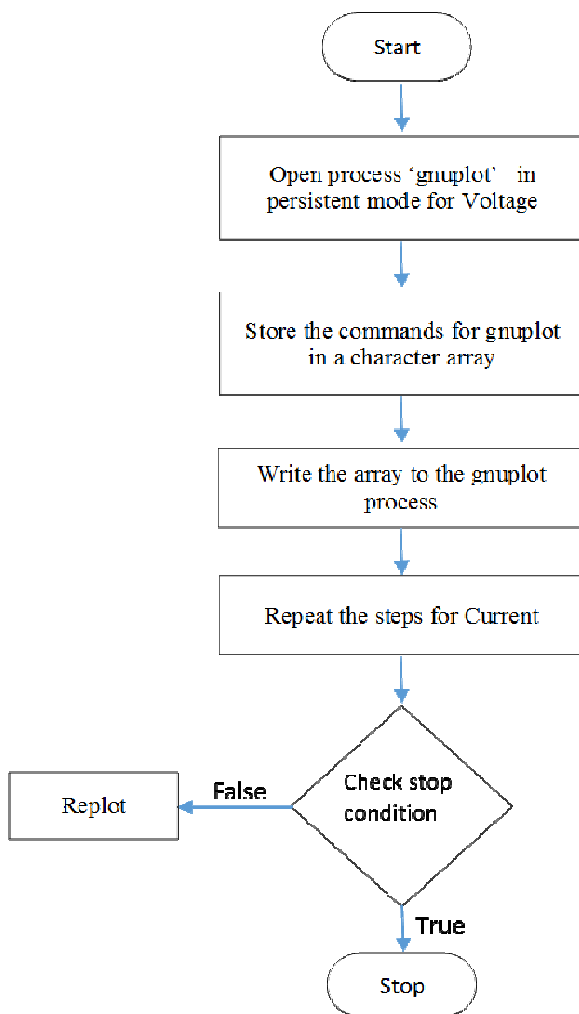
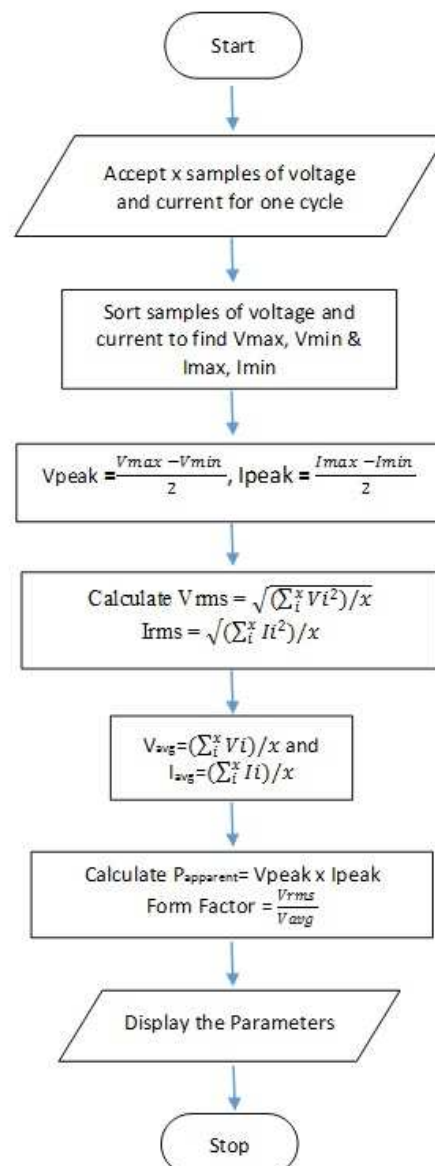


Fig. 4. Flowchart for plotting



## VI. RESULTS AND DISCUSSIONS

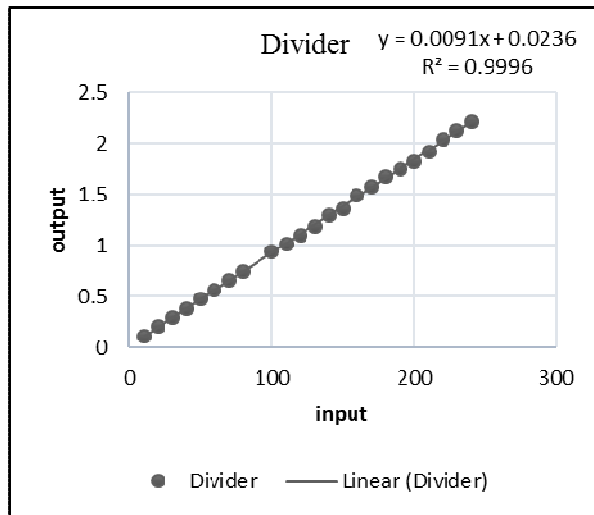


Fig. 6. Observed linearity of divider

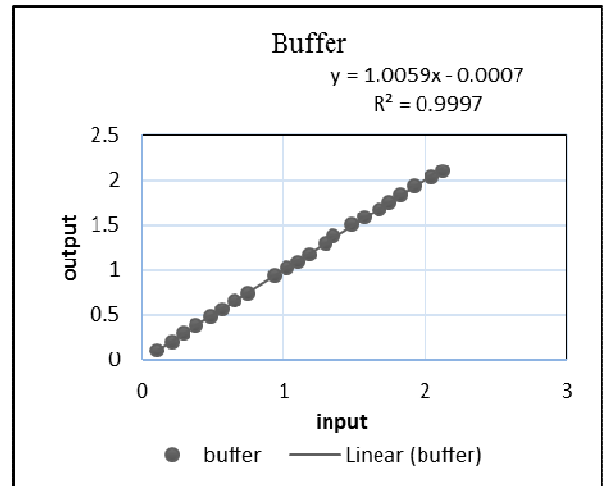


Fig. 8. Observed linearity of buffer

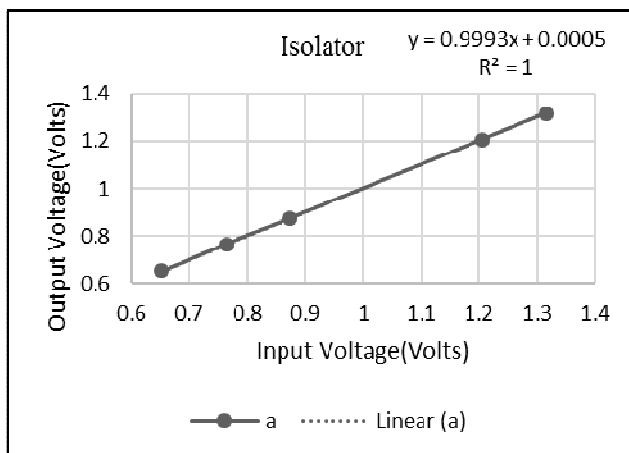


Fig. 7. Observed linearity of isolator

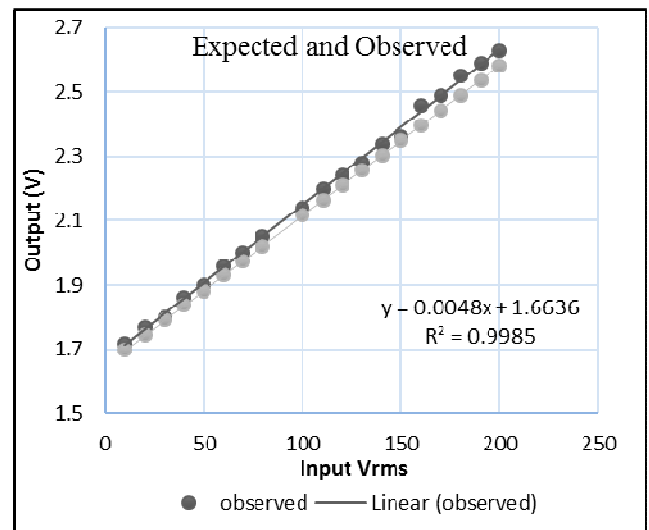


Fig. 9. Input Voltage at divider v/s Output voltage after DC biasing

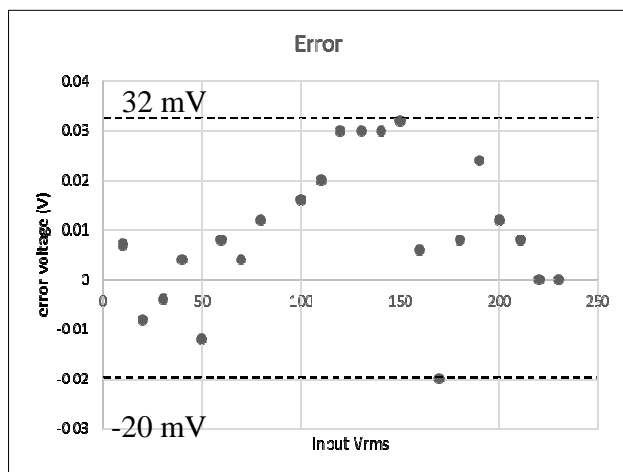


Fig. 10. Error

From fig.6, fig.7 and fig.8 it can be observed that each component of circuit works almost linearly. Figure 9 shows the comparison between expected and observed output of signal conditioning circuit. From Fig. 10 it is observed that the error lies within the range  $\pm 30\text{mV}$ . Mapping this error to  $1000\text{Vpp}$  gives error of  $10\text{V}$ . The circuit gives an error of only 1%.

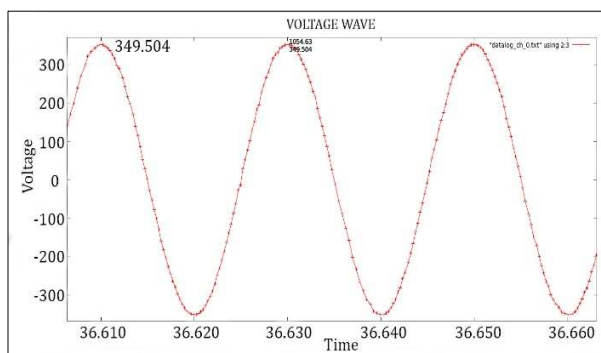


Fig. 11. Plotted Voltage Wave on gnuplot at 240 V (RMS)

## VII. APPLICATIONS

1. To monitor the transients in the power supply at CRL, Ooty. To monitor the effect of various loads on power supply. To observe the effect of variation of power supply on experiments.
2. Home power monitoring system.
3. Monitoring system for industrial and commercial power sources.

## VIII. CONCLUSION

Monitoring of power sources helps to identify the causes of transients, dips and other variations in the power. Measures can be taken to reduce these causes to reduce its effect on sensitive experiments. Increasing the number of USB packets transferred at a time causes non uniform delay which distorts the actual shape of waveform.

## IX. FUTURE DEVELOPMENTS

1. Replacing DC biasing circuit with digital potentiometer to get programmable DC shift.
2. Use of programmable gain amplifier to amplify small signal to full range of ADC in order to increase the resolution.
3. Replacing the USB communication protocol with TCP/IP protocol to acquire the data from larger distance.

## X. ACKNOWLEDGMENT

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## REFERENCES

- [1] Gnuplot Full User manual [www.gnuplot.info](http://www.gnuplot.info)
- [2] Gnuplot examples [www.gnuplotting.org](http://www.gnuplotting.org)
- [3] PIC18F87J50 datasheet  
[www.microchip.com/wwwproducts/en/PIC18F87J50](http://www.microchip.com/wwwproducts/en/PIC18F87J50)
- [4] Ramakant A. Gaykwad, “Op-Amps and Linear Integrated Circuits”, fourth edition.