

CHAPTER-I

INTRODUCTION

1.1 INTRODUCTION:

Electronic energy meter for the measurement of energy by the electric utility and the consumer have been accepted for the accurate measurement of energy consumed. The revenue of the electric utility depends on the electric energy being built to the consumer. It is therefore necessary, the energy meter reading should being conformed to the energy consumed by the consumer. If the energy meter reads less then there is a loss of revenue to the electric utility where as if the meter reads more there is a loss to the consumer and the consumer is unsatisfied.

Till 2006, conventional electromagnetic energy meter was in use in India for recording the electric consumed by the consumers. These electronic energy meters have many drawbacks and most of the time record less energy. This results into the loss of revenue to the electric utility. To overcome the drawbacks of electromagnetic energy meter, electronic energy meters have been adopted and replaced the conventional electromagnetic meter. India is a vast country and crores of energy meters are required to be tested and calibrated for the replacement of existing conventional energy meter. This big task is not possible with the manual testing and calibration facilities. Automation for the testing and calibration of electronic energy meter is a feasible solution. The author has developed an algorithm based on Labview for the testing of electronic energy meter. The results have been conformed with alternative testing method using hall effect voltage and current sensor. The result confronts each other.

1.2 PRINCIPLE WORKING OF ELECTRONIC ENERGY METER

The block diagram represents the different component of a single phase electronic energy meter as such current transformer (CT), analog to digital converter, programmable gain amplifier (PGA), digital to frequency converter, multiplier and display.

The Energy-measuring integrated circuit accepts voltage inputs representing local voltage and current in an electrical power system and converts them to digital using oversampling A/D converters. An on-chip digital processor continuously computes the product of the two signals, which is proportional to instantaneous power.

The most general purpose member of the family, the AD7750 (Figure 1), low-pass filters the computed product, then uses digital-to-frequency conversion to output a complementary pair of pulse trains of frequency proportional to the instantaneous real power—for driving a counter or two-phase stepping motor— plus a higher-frequency output, suitable for calibration and test.

A typical meter will convert signals proportional to instantaneous voltage and current to digital, then compute average and instantaneous real power, reactive power, active energy, etc., and

transmit the information serially. Digital signal processing (DSP)-based products perform multiplication and other calculations on current and voltage signals that have been digitized with on-chip analog-to-digital converters (ADCs). Processing the signals digitally provides stable and accurate calculations over time despite variations in the environment. And hence, the output power, energy consumed and other important data are displayed on the screen.

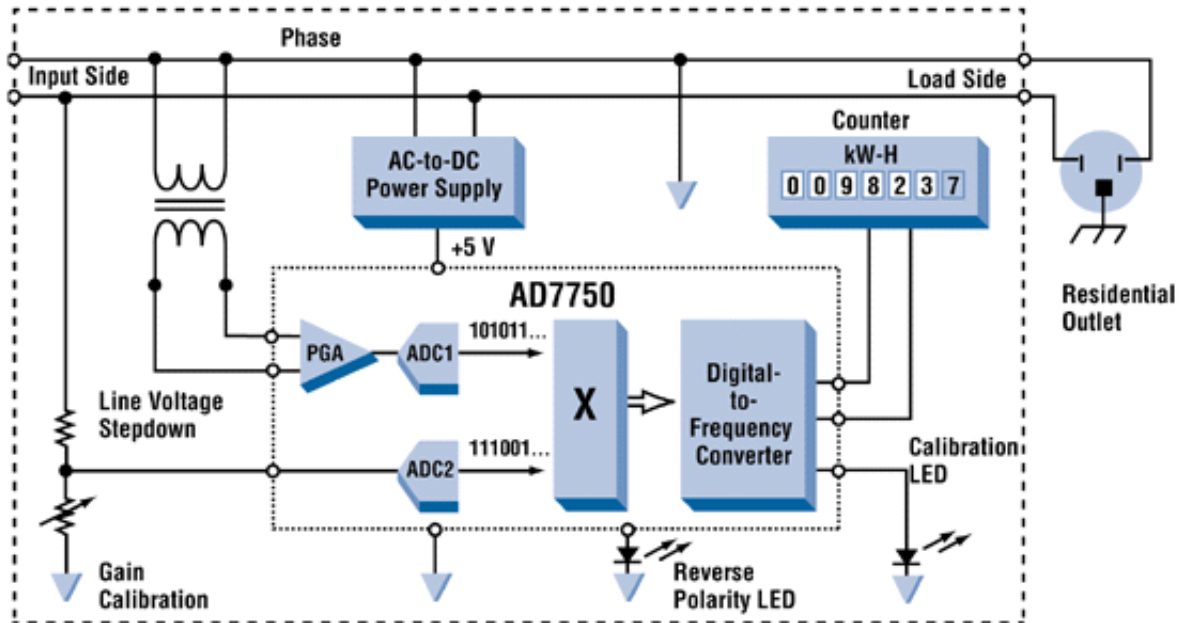


Fig 1.1 Functional block diagram of the single phase energy meter

CT: Current Transformer

PGA: Programmable Gain Amplifier

ADC: Analog to Digital Converter

1.3 FEATURES OF LABVIEW

Lab VIEW (Abbreviation of laboratory virtual instrumentation engineering workbench) is a platform and development environment for a visual programming language from National instruments. The purpose of such programming is automating the usage of processing and measuring the equipment in any laboratory setup. It is commonly used for data acquisition, instrument control and industrial automation on a variety of platform including Microsoft windows. The programming language used in labVIEW is referred as 'data flow programming' language. Execution is determined by the structure of a graphical block diagram on which

programmer connects different function nodes by drawing wires. These wires propagate the variables and any node can execute as soon as all its input data become available. Similarly in case of multiple nodes, this programming is capable of parallel execution. In order to have the graphical display of input and out variables, graphical programming methods have been adopted.

Lab VIEW program are also called virtual instruments (VI's). Each VI has three components: a block diagram, front panel and a connector panel. Block diagram consist of many virtual representation of component in block form, assembled as per the requirement of programmer. The connector panel is used to represent VI in the block diagram's of other calling VI's. Control and indicators on the front panel allow an operator to input data into or extract data from a running virtual instrument. However the front panel can also serve as a user interface or when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the given node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program.

1.4 ADVANTAGES OF AUTOMATION

Even though automation has certain technical limitation and high initial investment, it has been widely accepted because of certain advantages:

- Replacing human operators in task that involve hard work or monotonous work.
- Replacing human in tasks done in dangerous environment (i.e space, nuclear facility etc).
- High degree of accuracy is achieved.
- Performing task that are beyond human capability of size, weight, speed, endurance etc.
- Economy empowerment: Automation may improve the economy of enterprises.

1.5 DISSECTION OF DISSERTATION

The material of this dissertation has been organized in seven chapters. The contents of the chapters are briefly outlined as indicated below.

Chapter-1 Discusses about the introductory part of project, describing elementary features of electronic energy meter and Lab VIEW.

Chapter-2 Discussion on literature review.

Chapter-3 Discusses the hardware components of electronic energy meter.

Chapter-4 Deals with brief discussion on calibration of electronic energy meter.

Chapter-5 Discusses about the auxiliary components and interfacing devices.

Chapter-6 Discusses about the system integration for the calibration purpose.

Chapter -7 Results and Discussion.

CHAPTER-II

LITERATURE REVIEW

2.1 INTRODUCTION

Calibration is a comparison between measurements of a quantity made by two different devices under the similar condition or in a similar way. The devices used in measurement are referred by different name as such the device known with known correctness is called standard instrument and second device is called test instrument. The quantity to be measured may be anything like-voltage, current, power, flow etc. In the present context electrical energy is the quantity to be measured. Electrical energy is defined as integral of power with respect to time.

Electric energy meter is the device used to indicate the energy consumed over a period of time. This energy is referred here as the test instrument. Another measure of electrical energy is taken with the help of Lab VIEW program. This virtual energy meter, working in real time domain, act as a standard instrument. Comparing the outcome of these instrument (Test and standard instrument)

2.2 DEVELOPMENT HISTORY OF LABVIEW AND ITS IMPORTANCE:

In recent years, the rapid development of micro-electronics technology, computer technology, network communication technology and software technology promote the rapid development of virtual machines technology. In LabVIEW environment, real time power quality monitoring can be developed using Virtual Instrumentation concept. This is done with data acquisition system, which can transmit the measured signal any far-away place via guided or unguided media without distorting the original signals.

Virtual Instrumentation is an interdisciplinary field that merges sensing, hardware, and software technologies in order to create flexible and sophisticated instruments for control and monitoring applications. The concept of virtual instrumentation was born in late 1970s, when microprocessor technology enabled a machine's function to be more easily changed by changing its software. The flexibility is possible as the capabilities of a virtual instrument depend very little on dedicated hardware. A history of virtual instrumentation is characterized by continuous

increase of flexibility and scalability of measurement equipment. Nearly all of the instrument control programs were written in BASIC, because it had been the dominant language used with dedicated instrument controllers. It required engineers and other users to become programmers before becoming instrument users, so it was hard for them to exploit potential that computerized instrumentation could bring. Therefore, an important milestone in the history of virtual instrumentation happened in 1986, when National Instruments introduced Lab VIEW 1.0 on a PC platform. Lab VIEW introduced graphical user interfaces and visual programming into computerized instrumentation, joining simplicity of a user interface operation with increased capabilities of computers. Today, the PC is the platform on which most measurements are made, and the graphical user interface has made measurements user-friendlier. As a result, virtual instrumentation made possible decrease in price of an instrument. As the virtual instrument depends very little on dedicated hardware, a customer could now use his own computer, while an instrument manufacturer could supply only what the user could not get in the general market.

Virtual instrumentation combines mainstream commercial technologies, such as the PC, with flexible software and wide variety of measurement and control hardware, so engineers and scientists can create user defined system that meet their exact application needs. With Virtual instrumentation, engineers and scientist reduce development time, design higher quality products, and lower their design costs.

Virtual Instruments is basically used for displaying test or measurement data collected by the external device on instruments like panels on a computer screen. Thus Virtual Instrumentation uses a general purpose computer to mimic real instruments with their controls and displays.

The virtual instrument technology platform for the development of power quality monitoring system is flexible, easy to upgrade, able to overcome the traditional test and measurement system shortcomings, such as a single function and the complexity of the upgrade. Their functions are chosen by users and can be extended or modified according to user's requirements in contrast with traditional instrumentation (millimeters, oscilloscopes etc.) where the functions are vendor defined by hardware.

2.3 HISTORICAL PERSPECTIVE OF ENERGY METER

An electricity meter or energy meter is a device that measures the amount of electric energy consumed by a residence, business, or an electrically powered device. Electricity meters are typically calibrated in billing units, the most common one being the kilowatt hour. Periodic readings of electric meters establish billing cycles and energy used during a cycle.

In settings when energy savings during certain periods are desired, meters may measure demand, the maximum use of power in some interval. In some areas, the electric rates are higher during certain times of day, to encourage reduction in use. Also, in some areas meters have relays to turn off nonessential equipment.

Direct Current (DC)

As commercial use of electric energy spread in the 1880s, it became increasingly important that an electric energy meter, similar to the then existing gas meters, was required to properly bill customers for the cost of energy, instead of billing for a fixed number of lamps per month. Many experimental types of meter were developed. Edison at first worked on a DC electromechanical meter with a direct reading register, but instead developed an electrochemical metering system, which used an electrolytic cell to totalize current consumption. At periodic intervals the plates were removed, weighed, and the customer billed. The electrochemical meter was labor-intensive to read and not well received by customers. In 1885 Ferranti offered a mercury motor meter with a register similar to gas meters; this had the advantage that the consumer could easily read the meter and verify consumption. The first accurate, recording electricity consumption meter was a DC meter by Dr Hermann Aron, who patented it in 1883. Hugo Hirst of the British General Electric Company introduced it commercially into Great Britain from 1888. Meters had been used prior to this, but they measured the rate of energy consumption at that particular moment, i.e. the electric power. Aron's meter recorded the total energy used over time, and showed it on a series of clock dials.

Alternating Current (AC)

The first specimen of the AC kilowatt-hour meter produced on the basis of Hungarian Ottó Bláthy's patent and named after him was presented by the Ganz Works at the Frankfurt Fair in the autumn of 1889, and the first induction kilowatt-hour meter was already marketed by the factory at the end of

the same year. These were the first alternating-current watt meters, known by the name of Bláthy-meters. The AC kilowatt hour meters used at present operate on the same principle as Bláthy's original invention. Also around 1889, Elihu Thomson of the American General Electric company developed a recording watt meter (watt-hour meter) based on an ironless commutator motor. This meter overcame the disadvantages of the electrochemical type and could operate on either alternating or direct current.

In 1894 Oliver Shallenberger of the Westinghouse Electric Corporation applied the induction principle previously used only in AC ampere-hour meters to produce a watt-hour meter of the modern electromechanical form, using an induction disk whose rotational speed was made proportional to the power in the circuit. The Bláthy meter was similar to Shallenberger and Thomson meter in that they are two-phase motor meter. Although the induction meter would only work on alternating current, it eliminated the delicate and troublesome commutator of the Thomson design. Shallenberger fell ill and was unable to refine his initial large and heavy design, although he did also develop a polyphase version.

UNIT OF MEASUREMENT:

The most common unit of measurement on the electricity meter is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Some electricity companies use the SI megajoule instead. Demand is normally measured in watts, but averaged over a period, most often a quarter or half hour. Reactive power is measured in "Volt-amperes reactive", (varh) in kilovar-hours. By convention, a "lagging" or inductive load, such as a motor, will have positive reactive power. A "leading", or capacitive load, will have negative reactive power. Volt-amperes measures all power passed through a distribution network, including reactive and actual. This is equal to the product of root-mean-square volts and amperes.

Distortion of the electric current by loads is measured in several ways. Power factor is the ratio of resistive (or real power) to volt-amperes. A capacitive load has a leading power factor, and an inductive load has a lagging power factor. A purely resistive load (such as a filament lamp, heater or kettle) exhibits a power factor of 1. Current harmonics are a measure of distortion of the wave form. For example, electronic loads such as computer power supplies draw their current at the voltage peak to fill their internal storage elements. This can lead to a significant voltage drop near the supply voltage peak which shows as a flattening of the voltage waveform. This flattening causes odd harmonics which are not permissible if they exceed specific limits, as they

are not only wasteful, but may interfere with the operation of other equipment. Harmonic emissions are mandated by law in EU and other countries to fall within specified limits.

TYPES OF ENERGY METER

Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) and finding the product of these to give instantaneous electrical power (watts) which is then integrated against time to give energy used (joules, kilowatt-hours etc.). Meters for smaller services (such as small residential customers) can be connected directly in-line between source and customer. For larger loads, more than about 200 ampere of load, current transformers are used, so that the meter can be located other than in line with the service conductors. The meters fall into two basic categories, electromechanical and electronic.

- **Electromechanical meters**

The most common type of electricity meter is the electromechanical induction watt-hour meter.

The electromechanical induction meter operates by counting the revolutions of an aluminium disc which is made to rotate at a speed proportional to the power. The number of revolutions is thus proportional to the energy usage. It consumes a small amount of power, typically around 2 watts.

The metallic disc is acted upon by two coils. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees using a lag coil. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current and voltage. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc. The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power being used. The disc drives a register mechanism which integrates the speed of the disc over time by counting revolutions, much like the odometer in a car, in order to render a measurement of the total energy used over a period of time.

The type of meter described above is used on a single-phase AC supply. Different phase configurations use additional voltage and current coils.



Fig 2.1 Three-phase electromechanical induction meter

Three-phase electromechanical induction meter, metering 100 A 230/400 V supply. Horizontal aluminum rotor disc is visible in center of meter.

The amount of energy represented by one revolution of the disc is denoted by the symbol Kh which is given in units of watt-hours per revolution. The value 7.2 is commonly seen. Using the value of Kh , one can determine their power consumption at any given time by timing the disc with a stopwatch. If the time in seconds taken by the disc to complete one revolution is t ,

$$P = \frac{3600 \cdot Kh}{t}$$

then the power in watts is

Most domestic electricity meters must be read manually, whether by a representative of the power company or by the customer. Where the customer reads the meter, the reading may be supplied to the power company by telephone, post or over the internet. The electricity company will normally require a visit by a company representative at least annually in order to verify customer-supplied readings and to make a basic safety check of the meter.

In an induction type meter, creep is a phenomenon that can adversely affect accuracy that occurs when the meter disc rotates continuously with potential applied and the load terminals open circuited. A test for error due to creep is called a creep test.

Electronic meters

Electronic meters display the energy used on an LCD or LED display, and can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as maximum demand, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours.

- Multiple tariff (variable rate) meters

Electricity retailers may wish to charge customers different tariffs at different times of the day to better reflect the costs of generation and transmission. Since it is typically not cost effective to store significant amounts of electricity during a period of low demand for use during a period of high demand, costs will vary significantly depending on the time of day. Low cost generation capacity (base load) such as nuclear can take many hours to start, meaning a surplus in times of low demand, whereas high cost but flexible generating capacity (such as gas turbines) must be kept available to respond at a moment's notice (spinning reserve) to peak demand, perhaps being used for a few minutes per day, which is very expensive.

Some multiple tariff meters use different tariffs for different amounts of demand. These are usually industrial meters.

- Appliance energy meters
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Plug in electricity meters (or "Plug load" meters) measure energy used by individual appliances. The meter is plugged into an outlet, and the appliance to be measured is plugged into the meter. Such meters can help in energy conservation by identifying major energy users, or devices that consume excessive standby power. A power meter can often be borrowed from the local power authorities or a local public library.

- Home energy monitor

A potentially powerful means to reduce household energy consumption is to provide convenient real-time feedback to users so they can change their energy using behavior. Recently, low-cost energy feedback displays have become available. A study using a consumer-readable meter in

500 Ontario homes by Hydro One showed an average 6.5% drop in total electricity use when compared with a similarly sized control group. Hydro One subsequently offered free power monitors to 30,000 customers based on the success of the pilot. Projects such as Google Power Meter, take information from a smart meter and make it more readily available to users to help encourage conservation.

- Smart meters

Smart meters go a step further than simple AMR (automatic meter reading). They offer additional functionality including a real-time or near real-time reads, power outage notification, and power quality monitoring. They allow price setting agencies to introduce different prices for consumption based on the time of day and the season.

These price differences can be used to reduce peaks in demand (load shifting or peak lopping), reducing the need for additional power plants and in particular the higher polluting and costly to operate natural gas powered peaker plants. The feedback they provide to consumers has also been shown to cut overall energy consumption

Another type of smart meter uses nonintrusive load monitoring to automatically determine the number and type of appliances in a residence, how much energy each uses and when. This meter is used by electric utilities to do surveys of energy use. It eliminates the need to put timers on all of the appliances in a house to determine how much energy each uses.

- Prepayment meters



Fig 2.2 Prepayment meters

Prepayment meter and magnetic stripetokens, from a rented accommodation in the UK. The button labeled A displays information and statistics such as current tariff and remaining credit. The button labeled B activates a small amount of emergency credit should the customer run out



In South Africa, Sudan and Northern Ireland prepaid meters are recharged by entering a unique, encoded twenty digit number using a keypad. This makes the tokens, essentially a slip of paper, very cheap to produce.

Around the world, experiments are going on, especially in developing countries, to test prepayment systems. In some cases, prepayment meters have not been accepted by customers. There are various groups, such as the Standard Transfer Specification (STS) association, which promote common standards for prepayment metering systems across manufacturers. Prepaid meters using the STS standard are used in many countries.

- Power export metering

Many electricity customers are installing their own electricity generating equipment, whether for reasons of economy, redundancy or environmental reasons. When a customer is generating more electricity than required for his own use, the surplus may be exported back to the power grid. Customers that generate back into the "grid" usually must have special equipment and/or safety devices to protect the grid components (as well as the customer's own) in case of faults (electrical short circuits) or maintenance of the grid (say voltage potential on a downed line going into an exporting customers facility).

2.4 LITERATURE SURVEY

A literature review of various papers published and presented in various international conferences on energy metering and virtual instrumentation was carried out and briefly summarized as follows:

Robarto Caceres, et al. [1] studied active electric energy meters behavior of induction and electronic types.

The electromagnetic or induction meters are very reliable. The tendency for the curve of error displacement during the operating time is toward negative values, mainly for low load current

values. After 10 years in service, the negative error is bigger in meters that do not have magnetic suspension. They admit fraud easily, due to the little complexity and accessibility to their mechanism. The electric energy measurement using induction equipment is not obsolete, if it delimits it to the active energy measurement and if non linear loads (Harmonic Distortion) are not considered.

F. Calegari [2] has described energy measurement in residential single phase networks, the power and energy measurements through a low-cost electronic solid-state digital meter, for the non sinusoidal case, needs to optimization of the signal

acquisition system. Otherwise noticeable errors are introduced. Furthermore, the low cost implementation of some definitions is difficult, and these can only be approximated. The energy meter IC based architecture is more flexible and more proper to integration inside the communication technologies for the home automation. M Wada and O. Nakamura developed a remote meter reading system for distribution automation. The remote meter reading system had been field operated since 1989. As a result, it has been confirmed that in many respects including functions and performance of the system, it is feasible to start commercial operation of the system. However, further improvement in the function and performance of the system needed as linkage of the system to home automation systems and the provision of security service so that one can meet the sophisticated needs of customers. The perception of reliability of any measurement instrumentation should not only be limited to long life expectancy but should also include consistent performance

M. Nagaraju, et al [3] have described networked Electronic Energy meters with power quality analysis in addition to the obvious advantages (insensitivity, manufacturability, reliability and digital / field calibration) of electronic energy meter over their electro mechanical counterparts, Networked electronic energy meters will revolutionize future power systems in terms of better integration, planning, control, maintenance and billing. In addition, meters that conform to the P. 14.51.2 standard may be inter-networked through the world wide web, thereby opening a new vista in distributed monitoring, automation and control.

Antonio Barrierm et al [4] presented an energy management system for rational electricity use reducing cost and consumption. The emphasis is placed on extensive electronic energy metering and process data recording.

The R. De Vre, Huybrechts [5] presents a paper on Electronic Energy Meters – Principles, performances and tests. They discussed the various methods of power measurement like analog multipliers, transconductance multiplier, Hall effect multiplier, mark-space multiplier, multiplier with “Time” output, numerical multipliers etc. and the various test performed on Electronic watt - Hour meters to judge the performance of the watt-hour meters. The principles used in the electronic watt-hour meter permits to obtain very favorable metrological

characteristics and a favourable behaviour with regard to all sorts of influence from the environment

Benjamin Yue Zongbin [6] presented a paper on preparing for more competitive markets. Paper presents the implementation of remote energy metering systems and ERP software, even though there are flaws in the jewel of the simulation, it is drawing attentions of management and staff of each department to continuously improve efficiency of operation.

Henrik Lavric, et al.[7] described Hybrid Voltage amplifier for power calibrator with harmonics analysis capability.

By means of a novel topology combining linear and switching technique upgraded by the Supreme feed forward feedback control loop, a low distortion and power efficient system is obtained. Owing to the use of the output transformer, the output voltage is free of the dc component. This is extremely advantageous when calibrating energy meters containing voltage transformers. As expected, the amplifier meets the amplitude in accuracy and THD specifications. It is only the phase error that slightly exceeds the limit value when approaching the frequency of 70Hz. This can be compensated for by a voltage reference generator. Since the long-term inaccuracy depends only on the absolute stability of very few components in the supreme feedback circuit, it is believed that it will not exceed the limit value. Companied to the linear amplifier, the essential advantages of the hybrid voltage amplifier are low power losses when reactive loads are applied to the output when power calibrator is used.

A literature review of Bureau of Indian standard IS 13779 : 1999 [8] for ac static watt Hour meters of class 1 & class 2 accuracy has been also carried out. The specification describes and gives guidance for designing static watt hour meters of accuracy class-1 and 2, for the measurement of alternating current electrical active energy of frequency in the range 45 Hz to 55Hz for single

phase and three - phase balanced and unbalanced loads. It applies to their type tests, routine tests and acceptance tests.

Phang Yoke Yin and M. V. Chilukuri [9] developed a computer based data acquisition system that provides real-time monitoring of voltage and current at the customer's point of common coupling (PCC). Any power quality disturbances sustained by the user throughout the monitoring period were detected and recorded on remote PC. Post acquisition analysis was performed on the collected data

Qiu Tang, Zhaosheng Teng, Siyu Guo and Yaonan Wang [10] designed a multifunctional Virtual power quality monitoring system and implemented in LabVIEW environment. S-transform is introduced and applied to perform time-frequency analysis on power quality disturbances. The root mean square (RMS) value, the waveforms of three-phase voltage and current, the harmonic components, the total harmonic distortion(THD) and S transform analysis waveforms of the three-phase voltage and current signals can be calculated and displayed in the system. Furthermore, the remote transfer of measured results is implemented using the AppletVIEW Toolkit in LabVIEW adopting a B/S framework. Measurement results show the feasibility and validity of the system

H.E Wenhai [11] developed a new noise test system based on virtual instrument technology which comprises the testing technology, the computer technology and the network technology. In this new system, the sound card of personal computer is used as data acquired card (DAQ card) for acquiring noise signals. So the total test system is more economical. During testing, noise signals are acquired and processed simultaneity by this system. User can obtain the information of the acquired noise signals in time domain and frequency domain. It is known from the actual testing that the test efficiency and precision both are enhanced because of the use of this new system.

B. P. Alencar, J. I. Gomes Filho, R. A. Melo, and R. P. S. Leão [12] designed flicker meter using labVIEW on IEC 4-1561000

CHAPTER-III

ELECTRONIC ENERGY METER

3.1 INTRODUCTION

For many years, traditional electro mechanical meters have been the instrument used by utility companies to measure residential and commercial power consumption. As the deregulation of the generation and distribution of power progress, the price for electricity becomes increasingly competitive. Consumers are also demanding better customer service, higher energy measurement accuracy and more timely data. Utility companies are being forced to find solutions that will enable more sophisticated energy measurement methods, to achieve these goals an electronic energy meter is considered the lowest cost solution. The electronic energy meter is an ac static meter and is based on energy metering IC (AD7751/ADE7752). The main features of the meter are

- (i) The most distinctive features is that it continuously monitors the phase and neutral (return) currents. A fault condition occurs if the two currents differ by more than 12.5%. This feature prevents tempering by the customers in terms of using earth as returns wire in place of neutral because it calculates power on the basis of larger current and even if one of the two wire does not carry any current. This feature also helps to the customer in paying appropriate bill to the electricity board.
- (ii) It is a low cost, single chip solution for electrical energy measurement.
- (iii) It also has direct drive capability for electro mechanical counters as like conventional meters.
- (iv) It has a high frequency pulse output for calibration and communication purposes.
- (v) High accuracy and low wear and tear because it contains no moving part.
- (vi) The energy monitoring IC supplies average real power on the frequency outputs F1 and F2.
- (vii) High accuracy over large variation in environmental conditions and aging.
- (viii) Low effect of stray magnetic field.
- (ix) Very minor effect of transportation & impact.

- (x) On chip creep protection.
- (xi) Single 5V supply, low power 15mw for single phase and 60 mw in case of three phase meters.

The electronic energy meters are more vulnerable to EMI disturbances and may also act as a source of polluting power line as well as electromagnetic environment due to use of SMPS, Clock & processing circuits etc.

3.2 FUNCTIONAL BLOCK DIAGRAM OF ELECTRONIC ENERGY METER

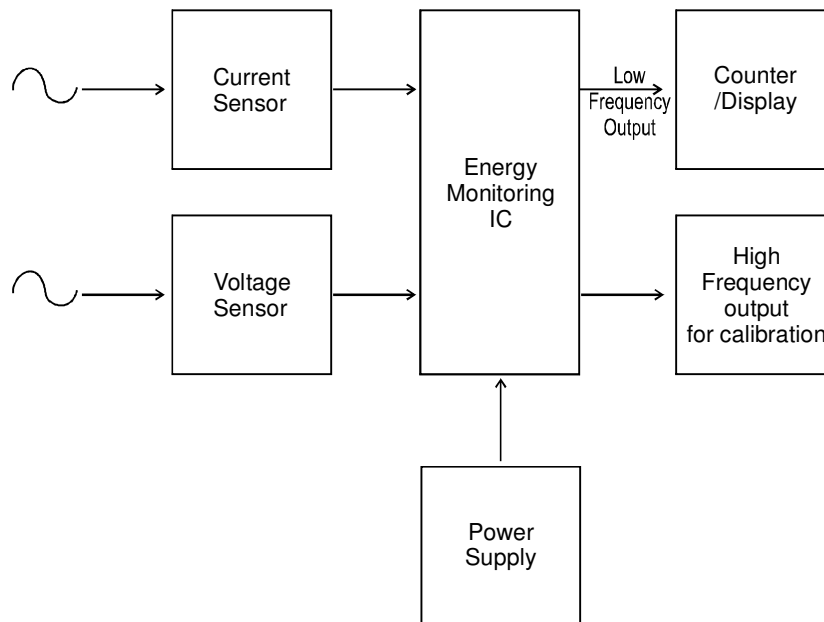


Fig. 3.1 Block diagram of an electronic energy meter

A block diagram of an Electronic Energy Meter is shown in figure . The current sensor carries the current of the circuit and converts it to the voltage of suitable magnitude useful for Energy Metering IC usually of the order of milli volts (± 330 mV). The voltage sensor carries the voltage of the circuit and reduced it to the utilization level of IC which is around 300mV. Energy metering IC first filters out the dc offset present either from the current signal or voltage signal then the instantaneous values of the voltages of the current channel and voltage channels are multiplied to give the instantaneous power. This power is filtered out by the low pass filter having cut off frequency as 50Hz so that average value of power is obtained, at low frequency output an integrator is used which gives the average value of energy to drive an electromechanical counter. Due to the low integration time, we have another output of high frequency for calibration purposes. In case of three phase energy meter, there will be three

current sensor and these voltage sensor to sense the current and voltage of all the three phases and an adder in addition to it for sum-up the power of all the three phases.

3.3 DESCRIPTION OF HARDWARE COMPONENTS

The integrated circuits of electronic energy meter consist mainly of five parts:

- a. Signal conditioning
- b. Power supply
- c. Energy monitoring IC
- d. counter/display

DESCRIPTION

(a) SIGNAL CONDITIONING

Energy meters must be capable of measuring with voltages up to at least 440 V and currents up to 100 A. These values cannot be easily handled by solid-state devices, and some signal conditioning is required. The simplest form is to use transformers to reduce signal levels to those that can be applied to printed circuitry. These transformers must be of good quality because any errors in transformation will be reflected in the overall error of the meter. Although compensation for ratio errors is possible by adjustment of circuit components, there is a danger of introducing instability if phase-angle compensation is attempted. Sensor acts here as a signal conditioner.

CURRENT SENSOR

A current transformer is the concept of inductance to sense current. A Current Transformer (CT) is made up of a coil wound around a ferrite core. The current-carrying wire is looped through the center of this winding, which creates a magnetic field in the winding of the Current Transformer and a voltage output proportional to the current in the conducting wire. The properties that affect the performance of a given Current Transformer are the dimensions of the core, the number of turns in the winding the diameter of the wire, the value of the load resistor, and the permeability and loss angle of the core material.

The phase error caused by the CT is compensated by a low-pass filter called antialiasing filter before the ADC inputs. In this way the error caused in energy measurement due to the phase mismatch between the current channel and voltage channel is avoided.

VOLTAGE SENSOR

It converts the input voltage of 230v to the range of milli volt so that it could be acquired by solid state circuitry. The output frequency or pulse rate in D7751 IC is related to the input voltage signals. In order to calibrate the meter, the line voltage needs to be attenuated down to 117.3 mV.

The line voltage attenuation is carried out by a simple resistor divider. The attenuation network should allow a calibration range of at least $\pm 30\%$ to allow for CT/Burden resistance tolerances and the on-chip reference tolerance of $\pm 8\%$. In addition, the topology of the network is such that the phase matching between channel 1 i.e. current channel and channel 2 i.e. voltage channel is preserved, when the attenuation is being adjusted i.e. when the calibration of the meter is carried out by varying the resistance of the attenuation network. In this process, -3 dB frequency of the RC low pass filter (initializing filter having cut off frequency as 900 KHz) and hence the phase response of the network on channel 2 should not vary. As it is clear from the circuit diagram the -3 dB frequency of this network is determined by the elements connected between $820\ \Omega$ resistor & $0.104\ \mu\text{F}$ capacitor. in voltage channel. Even with all the jumpers closed, the resistance 680kv is still much greater from the resistance of the RC filter hence variation in the resistance of the resistor chain will have little effect on the -3dB frequency of the network. Starting with $150\ \text{k}\Omega$ each jumper is closed in order of ascendance. If the calibration frequency on CF i.e. $16 \times 100\ \text{imp/kwh}$ (at $I_b = 10\text{A}$, CF is expected to be 1.07Hz) is exceeded when any jumper is closed, it should be opened again.

Since the AD7751 transfer function is extremely linear, a one-point calibration (at I_b) at unity power factor is all that is need to calibrate the meter. If the correct precautions have been taken at the design stage no calibration will be necessary at low power factor.

(b) POWER SUPPLY

Since the total power consumption in the voltage circuit including power supply is specified in section 4.4.1.1 of IEC 1036 (1996-9) must not increase by 2W and 10VA under nominal

conditions. However the total power consumption of AD7751 metering circuit is just only 0.085 watt, the power supply is designed to supply 2W at 5V. The functional block diagram of the power supply is given below

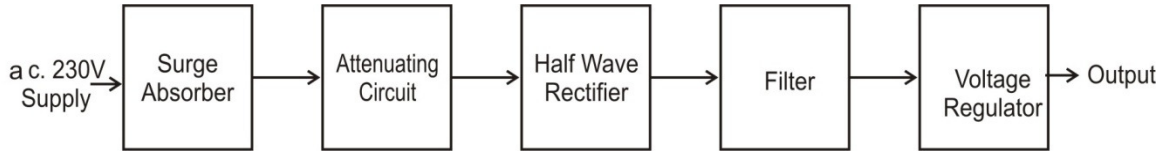


Figure 3.2 Functional block diagram of power supply

for single phase electronic energy meter.

Although resistor can be used in the emitter circuit of the transistor but we use capacitor in order to have more smooth d.c. voltage and to avoid sags in the voltage. 16V capacitor, just the next higher rating to 5V is used in order to provide head room at the output of transistor.

(c) ENERGY MONITORING IC

AD 7751 IC is a product-to-frequency (PFC) that can be configured for power measurement or voltage to frequency converter. The input signal to IC (which is the o/p of current and voltage sensors) is amplified with the help of op-amp. Figure below shows the functional block diagram.

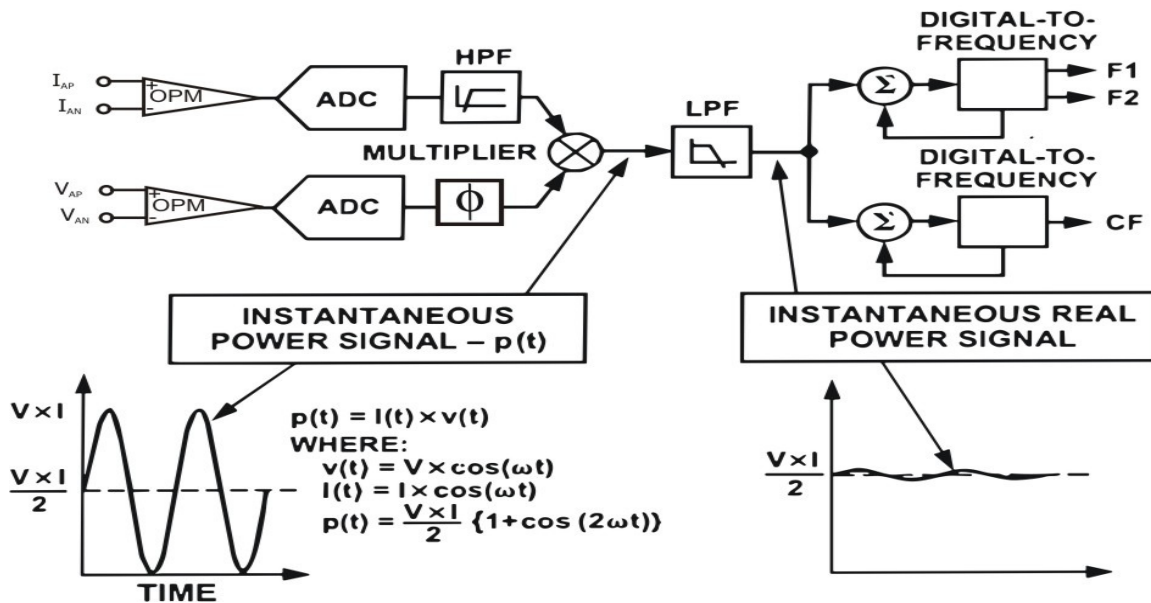


Fig. 3.3 Functional block dia. Of IC AD 7751

This signal is converted into digital with the help of two ADC. Successive approximation type is used. Its overall functioning can be divided into two parts-multiplication and integration of signals. Multiplication of signal gives the instantaneous power signal. NUMERICAL multiplier is used in electronic energy meter. If the power is given directly in numerical form, it results from the numerical values of pairs of synchronous samples U_{sp} and I_{sp} taken at regular intervals. The summation of these products multiplied by the sampling interval gives a representation of the instantaneous energy:

$\int p(t)dt = U_{sp}I_{sp}$. The implementation requires mainly an analog to-digital converter followed by a numerical computing device (generally a microprocessor). In practice the result is transmitted at regular intervals, multiples of Δt , to a totalizing display device. Next function is the integration with respect to time. The next step in the circuitry of a static meter is to perform the integration to turn the power signal into an energy reading:

$$\text{Energy } W = \int VI \cos\theta dt$$

Methods for integrating a current or voltage and producing pulses having a frequency proportional to the measured quantity have been fully explored in the development of digital

Voltmeters. In static meters two methods have been used: the charge-compensation method and dual-slope integration. The charge-compensation method utilizes an operational amplifier and a capacitor and trigger circuit. The output of the multiplier is allowed to charge the capacitor until a threshold voltage is reached when a predetermined charge is extracted from the capacitor, which then resumes charging. The charging rate is proportional to the power and a pulse is produced each time the trigger operates. The dual-slope integrator employs a capacitor that is

charged by the multiplier output to a threshold voltage, whereupon the input to the capacitor is reversed until a reverse limit is reached, when the input is again reversed. A pulse is produced at each alternate reversal. Both systems have merit in certain circumstances. In the first method the frequency of impulsion is limited by the time taken to extract the predetermined charge and the load range covered tends to be less than for the second method, although accuracy is less dependent on capacitor stability.

PIN DESCRIPTION

Figure shows the Pin diagram of AD7751 IC

The AD7751 combines two analog-to-digital converters, a digital multiplier, digital filters and a digital-to-frequency (DTF) converter onto one low cost integrated circuit. The AD7751 is fabricated on a double poly CMOS process (0.6 μ m) and retains its high accuracy by performing all multiplications and manipulations in the digital domain. The first thing to notice is that the analog signals are first converted to digital signals by the two second-order sigma-delta modulators. All subsequent signal processing is carried out in the digital domain. The main source of errors in an application is therefore in the analog-to-digital conversion process. For this reason great care must be taken when interfacing the analog inputs of the AD7751 to the transducer.

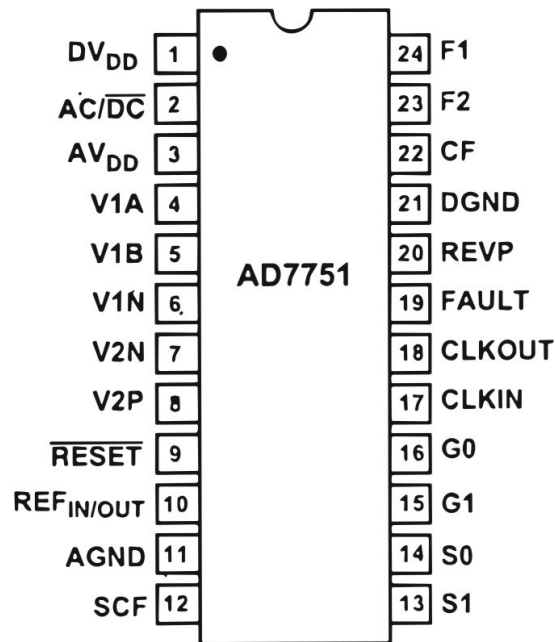


Fig. 3.4 Pin Diagram of AD7751 IC

PIN FUNCTION DESCRIPTIONS AD7751

Pin No.	Mnemonic	Description
1.	DV _{DD}	Digital Power Supply. This pin provides the supply voltage for the digital circuitry in the AD7751.
2.	AC/DC	High-Pass Filter Select. This logic input is used to enable the HPF in Channel 1
3.	AV _{DD}	Analog Power Supply. This pin provides the supply voltage for the analog circuitry in the AD7751.
4, 5.	V1A, V1B	Analog inputs for Channel 1.

(6.	V1N	Negative input pin for differential voltage inputs V1A and V1B.
7,8.	V2N, V2P	Negative and positive inputs for Channel 2 (voltage channel).
9.	RESET	Reset pin for the AD7751. A logic low in this pin will hold the ADCs and digital circuitry in a rest condition. Bringing this pin logic low will clear the AD7751 internal registers.
10.	REF _{IN/OUT}	The on-chip reference has a nominal value of 2.5V±8% and a typical temperature coefficient of 30 ppm/°C.
11.	AGND	This provides the ground reference for the analog circuitry in the AD7751, i.e., ADCs and reference.
12.	SCF	Select Calibration Frequency.
13,14	S1, S0	These logic inputs are used to select one of four possible references for the digital-to-frequency.
15,16	G1, G0	These logic inputs are used to select one of four possible gains for the analog inputs V1A and V1B. The possible gains are 1, 2, 8 and 16. See Analog Input section.

17.	CLKIN	An external clock can be provided at this logic input. Alternatively a crystal can be connected across CLKIN and CLKOUT to provide a clock source for the AD7751.
18.	CLKOUT	A crystal can be connected across this pin and CLKIN as described above to provide a clock source for the AD7751.
19.	FAULT	This logic output will go active high when a fault condition occurs. The logic output will be reset to zero when a fault condition is no longer detected.

20.	REVP	This logic output will go logic high when negative power is detected, i.e., when the phase angle between the voltage and current signals is greater than 90° .
21.	DGND	This provides the ground reference for the digital circuitry in the AD7751, i.e., multiplier, filters and digital-to-frequency converter.
22.	CF	Calibration Frequency Logic output.
23, 24	F2, F1	Low frequency logic outputs, F1 and F2 supply average real power information.

(d) COUNTER/DISPLAY

The display for an all-electronic meter is a digital readout using LED or similar displays with core-store memories. The frequency of output signal of an IC is used for either drive a stepper motor or glow LED at certain frequency depending on power consumed.

CHAPTER-IV

CALIBRATION OF ENERGY METER USING LABVIEW

4.1 INTRODUCTION

A brief discussion of the calibration of energy meter using LABVIEW is presented in the successive sections without extensive elaboration

Calibration is a comparison between measurement of a quantity made by two different devices under the similar condition or in a similar way. The devices used in measurement are referred by a different name as such the device with known correctness is called standard instrument and second device is called test instrument. The quantity to be measured may be anything like – voltage, current, power, flow etc. in the present context electric energy is the quantity to be measured. Electric energy is defined as the integral of power with respect to time.

$$E = \int_0^t p dt; E: \text{energy (kilowatt-hr)}, p: \text{power (Kilowatt)}, t: \text{time (hour)}$$

Electric energy meter is the device used to indicate the energy consumed over a period of time. This energy meter is referred here as the test instrument. Another measure of electrical energy is taken with virtual instrument designed with the help of LABVIEW software. This virtual energy meter, working in real time domain, act as a standard instrument. Comparing the outcome of these instruments (test and standard instrument) the given test instrument is calibrated.

4.2 SENSORS AND PHOTOTRANSISTORS

4.2.1 SENSOR

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

Two types of sensors are required in the project

A: voltage sensor

B: current sensor

These sensors convert the load voltage and current in the value range of milivolt to few volts which is in the domain of signal value that can be acquired by the DAQ card (as the signal with the maximum amplitude more than 12 volt cannot be acquired by the DAQ card). It can be said

that these sensors are used in order to acquire the signal that is needed for the calibration purpose. Hence, these sensors act as a facilitator.

4.2.2 PHOTOTRANSISTOR

Phototransistor is a junction transistor whose base signal is generated by illumination of base. The emitter current, and hence collector current increases with intensity of light. Phototransistor has been used in the project in order to achieve automated calibration of energy meter. The LED is mounted on the front face of the electronic energy meter whose blinking frequency depends on the power consumed by the load. This blinking LED is sensed by the photo sensors (phototransistor), which when incorporated in the circuit configuration generates the output impulse of the same frequency as that of blinking LED of electronic energy meter. This generated impulse signal is taken to through the DAQ card for the further processing. The generated impulse can be seen on the front panel of VI instruments. Exhaustive study of phototransistor is undertaken in the next chapter.

4.3 DATA ACQUISITION DEVICE

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (i.e. Parallel port, Serial port, USB port, etc.) or cards connected to slots (S-100 bus, AppleBus, ISA, Micro Channel architecture, PCI, PCI-E, etc.) in the Mother board.

Usually the space on the back of a PCI card is too small for all the connections needed, so an external Breakout box is required. The cable between this box and the PC can be expensive due to the many wires, and the required shielding. **Data acquisition** (abbreviated **DAQ**) is the process of sampling of real world physical conditions and conversion of the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition and data acquisition systems (abbreviated as **DAS**) typically involves the conversion of analog waveforms into digital values for processing. The components of data acquisition systems include:

- Sensors that convert physical parameters to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Data acquisition applications are controlled by software programs developed using various general purpose Programming languages such as BASIC, C (programming language), Fortran, Java (programming language), Lisp (programming language), Pascal (programming language). Graphical programming environments include Ladder logic, Visual C++, Visual Basic,

MATLAB, and LabVIEW. Main component of DAQ Card is ADC (analog to digital converter) which samples the analog signals on a regular basis and converts the amplitude at each sample time to a digital value with finite resolution. These are termed discrete-time, discrete ion value functions that are defined only at times specified by the sample rate and may have values determined by the resolution of the ADC. In other words, when an analog signal is digitized, an approximation has to be made based on the signal and the specifications used for data analysis. Resolution also plays a very important role here. The additional amplitude and temporal resolution are the two important factors that are to be discussed, but they may be expensive. To overcome this, there should be a clear idea on sampling. The process of sampling is based on Nyquist Shannon's sampling theorem.

Sampling Theorem

A fundamental rule of sampled data systems is that twice the highest frequency component in the signal. This is known as the Nyquist criterion stated as a formula it requires that $f_s/2 > f_a$, where f_s is the sampling frequency and f_a is the signal being sampled. Violating the Nyquist criteria is called under sampling, and results in aliasing where the signal will not be acquired in desired manner.

4.4 VIRTUAL INSTRUMENTATION

Virtual instrumentation sets a new standard in measurement by replacing bench top instruments. It uses software like NI labVIEW and hardware like PCI modules for data acquisition, instrument control and automation. VIs constructed with software are inexpensive, more accurate, maintenance free, can sense different physical quantities offering any range, compared to physical instruments. VIs works fast, handles repetitive tasks, processes data, stores results, generates reports, increases test safety and is controllable by the user. It saves time, money and increases productivity; customizability e.g. same code can be re-used for testing similar instruments. For any lab instead of buying individual instruments, VI can be employed in a computer for all measurements.

Virtual Instruments versus Traditional Instruments

Traditional instruments: Vendor defined, Function-specific; stand-alone with limited connectivity. Hardware is the key, Expensive, Closed, fixed functionality, slow turn on technology (5–10 year life Minimal economics of scale).

Virtual Instruments: User-defined, Application-oriented system with connectivity to networks, peripherals, and applications. Software is the key, low cost, reusable, Open, flexible functionality leveraging off familiar computer technology (Maximum economics of scale). Software minimizes development and maintenance costs.

4.4.1 PROGRAMMING TECHNIQUES

LabVIEW programs are called virtual instruments or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and millimeters. LabVIEW VIs contain three components: the front panel window, the block diagram, and the icon/connector pane.

Front panel Window

The Front panel window is the user interface for the VI. Fig.4.2 shows example of a front panel window. We create the front panel window with controls and indicators, which are the interactive input and output terminals of the VI, respectively.

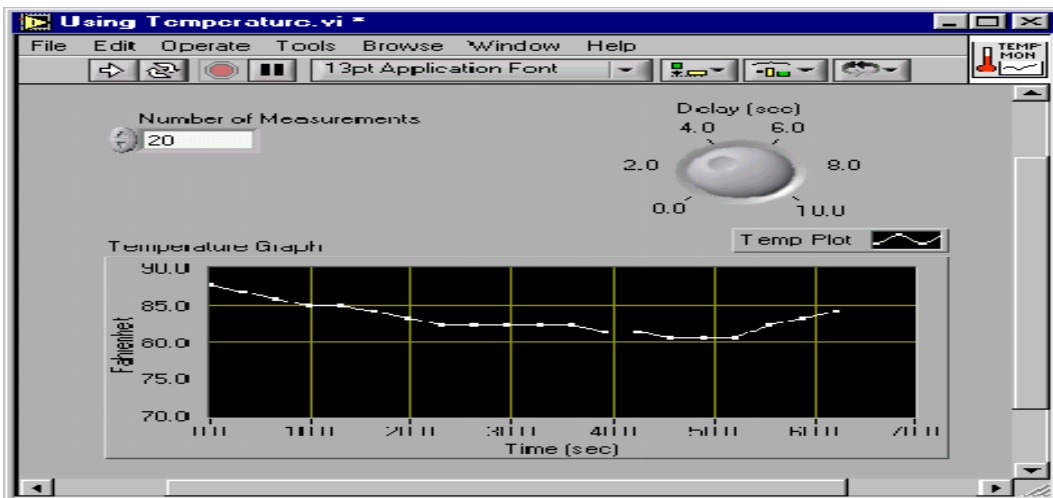


Fig.4.1 VI Front Panel

Block Diagram Window

After creating the Front Panel Window, we add code using graphical representation of functions to control the Front panel objects. Fig.3.3 shows an example of a block diagram window contains this graphical source code. Front panel objects appear as terminals on the block diagram.

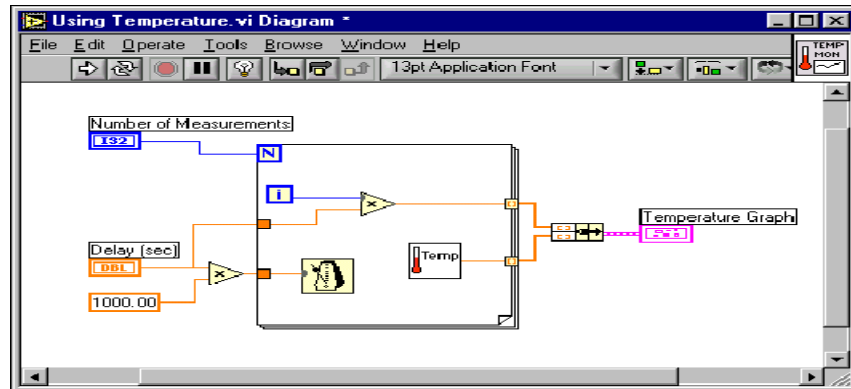
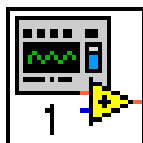


Fig. 4.2 VI Block Diagram

Icon and Connector Pane

A VI can be used as a **subVI**. A **subVI** is a VI that is used in another VI, similar to a function in a text based programming language. To use VI as a subVI, it must have an icon and connector Pane.



Every VI displays an icon, shown above, in the upper right corner of the front panel and block diagram windows. An icon is a graphical representation of a VI. It can contain text, images, or a combination of both. If we use a VI as a subVI, the icon identifies the subVI on the block diagram of the VI. The default icon contains a number that indicates how many new VIs we have opened since launching LabVIEW. Create custom icons to replace the default icon by right-clicking the icon in the upper right corner of the front panel or block diagram and selecting Edit Icon from the shortcut menu or by double-clicking the icon in the upper right corner of the front panel. We also can edit icons by selecting File»VI Properties, selecting General from the Category pull-down menu, and clicking the Edit Icon button. Use the tools on the left side of the Icon Editor Dialog box to create the icon design in the editing area. The normal size image of the

icon appears in the appropriate box to the right of the editing area, as shown in the following dialog box in Fig.3.4.

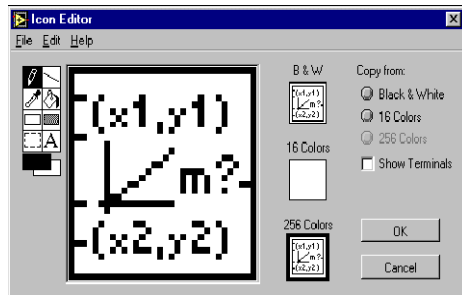


Fig. 4.3 Icon Editor

Use the options on the right side of the editing area to perform the following tasks:

- **Show Terminals**—Displays the terminal pattern of the connector pane.
- **OK**—Saves the drawing as the icon and returns to the front panel.
- **Cancel**—Returns to the front panel without saving any changes.

The menu bar in the **Icon Editor** dialog box contains more editing options such as **Undo**, **Redo**, **Cut**, **Copy**, **Paste**, and **Clear**.



To use a VI as a **subVI**, we need to build a connector pane, shown at left. The connector pane is a set of terminals that corresponds to the controls and indicators of that VI, similar to the parameter list of a function call in text-based programming languages. The connector pane defines the inputs and outputs we can wire to the VI so we can use it as a subVI. Define connections by assigning a front panel control or indicator to each of the connector pane terminals. To define a connector pane, right-click the icon in the upper right corner of the front panel window and select **Show Connector** from the shortcut menu. The connector pane replaces the icon. Each rectangle on the connector pane represents a terminal. Use the rectangles to assign inputs and outputs. The number of terminals LabVIEW displays on the connector pane depends on the number of controls and indicators on the front panel. The following front panel has four controls and one indicator, so LabVIEW displays four input terminals and one output terminal on the connector pane. We cannot access the connector pane from the icon in the block diagram window.

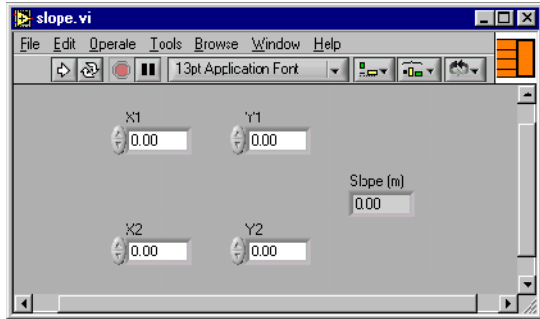


Fig. 4.4 shows icon/connector pane on top right side (orange colour box)

Palettes

LabVIEW has graphical, floating palettes to help you create and run VIs. The three palettes include the **Tools**, **Controls**, and **Functions** palettes. We can place these palettes anywhere on the screen.

Tools Palette

We can create, modify, and debug VIs using the tools located on the floating **Tools** palette. The **Tools** palette is available on the front panel and the block diagram. A tool is a special operating mode of the mouse cursor. When we select a tool, the cursor icon by itself changes to the tool icon. Use the tools to operate and modify front panel and block diagram objects. Next select **Window»Show Tools Palette** to display the **Tools** palette. We can place the **Tools** palette anywhere on the screen. Press the <Shift> key and right-click to display a temporary version of the **Tools** palette at the location of the cursor.



Fig 4.5 Tools palette



Use the Operating tool to change the values of a control or select the text within a control.



Use the Positioning tool to select, move, or resize objects



Use the Wiring tool to wire objects together on the block diagram.

Control and Function Palettes

The **Controls** and **Functions** contain sub-palettes of objects to create a VI. When click on sub-palette icon, the entire palette changes to the selected sub-palette. To use an object on the palettes, click the object and place it on the front panel or block diagram.

4.4.2 Starting a VI

When we launch LabVIEW, the following dialog box appears.



Fig 4.8 start window that appears when labVIEW is launched

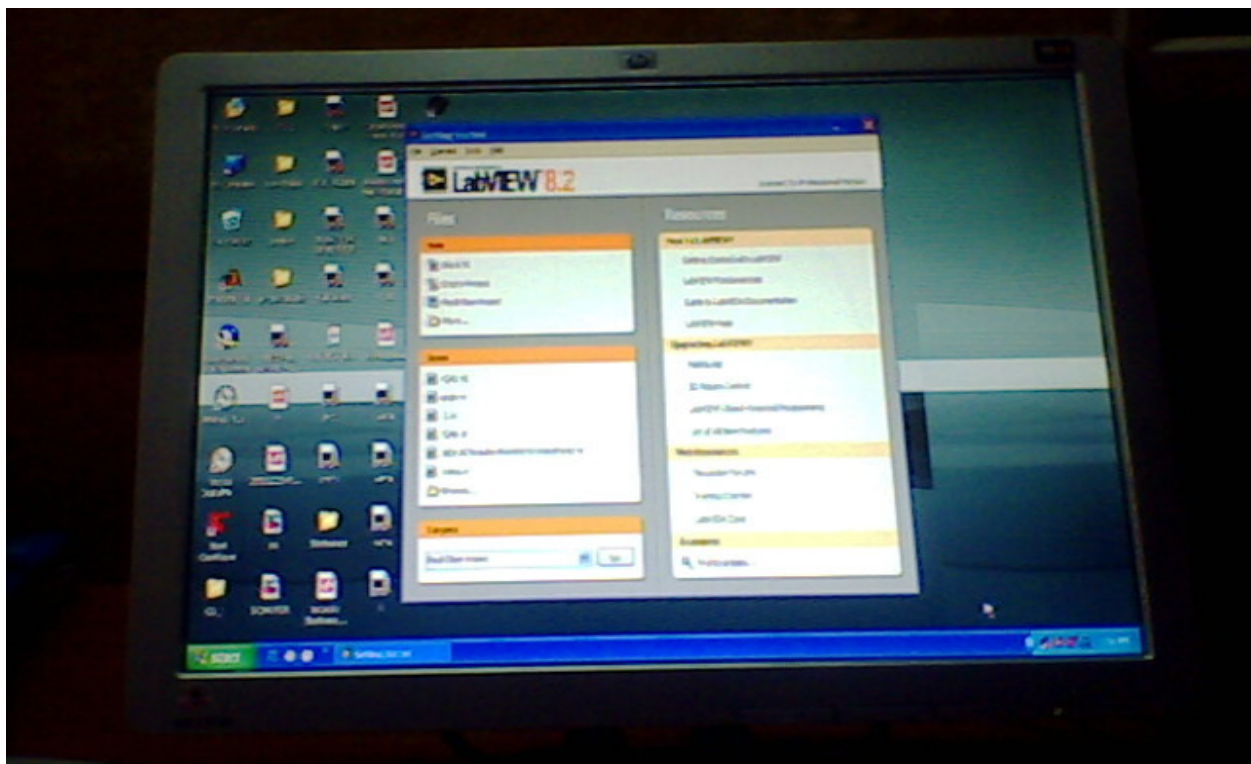


Fig 3.9 Dialog box for Getting Started of labVIEW

The **LabVIEW** dialog box includes the following components:

- Click the **New VI** button to create a new VI.
- Click the **Open VI** button to open an existing VI.
- Click the **DAQ Solutions** button to launch the DAQ Solution Wizard, which helps we find solutions for common DAQ applications.
- Click the **Search Examples** button to open a help file that lists and links to all available

LabVIEW example VIs

- Click the **LabVIEW Tutorial** button to open the interactive LabVIEW Tutorial. Use this tutorial to learn basic LabVIEW concepts.

4.4.3 Troubleshooting and Debugging VIs

Use the Context Help window and the LabVIEW Help to help you build and edit VIs.

Context Help Window

To display the **Context Help** window, select **Help » Show Context Help** or press the <Ctrl-H>key. When we move the cursor over front panel and block diagram objects, the **Context Help** window displays the icon for sub VIs, functions, constants, controls and indicators, with wires attached to each terminal. When we move the cursor over dialog box options, the **Context Help** window displays descriptions of those options. In the window, required connections are bold, recommended connections are plain text, and optional connections are dimmed or do not appear.

The following is an example **Context Help** window.

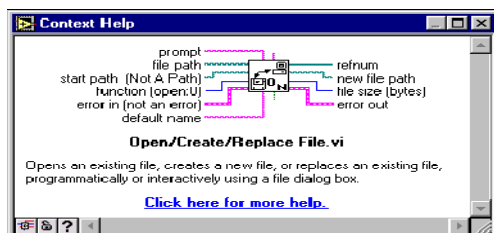


Fig. 4.10 shows Context Help

? Click the **More Help** button to display the corresponding topic in the LabVIEW Help, which describes the object in detail.

4. 5 Advantages of VI:

Long before people used typewriters, which were then replaced by the word processors that offered new levels of productivity and flexibility. Much as the same way, VIs will replace the physical instruments.



The picture on the top is that of a real instrument and the one on the bottom is that of a virtual one. Today's computer's graphic capabilities even make VIs look like real instruments. Virtual instruments are better connected to PC technologies widely used in industries. With VI, users can move applications seamlessly between several bus architectures, such as PC Card, plug-in DA hardware, and VXI. This portability offers the flexibility to take advantage of improved bus standards as they arise.

Customizability VIs are fully customizable. Range, accuracy, amount of information provided by them can be selected by users. Data can be saved in computer and send it over the internet. They can be made to sense any physical quantity offering any range with the use of corresponding sensors. A VI can be made to control any other instruments including another VI.

Increases productivity VIs are less expensive and maintenance free. They work very fast, handle repetitive tasks, process data, store results and also generate reports. Reuse of code is also possible. Thus the same code can be used for testing similar instruments which saves time and money. Doing things in less time would definitely mean being able to do more. With less time, money and human labour for the same product, the productivity increases rapidly.

Lowest cost for customers Physical instruments are not suited for extreme weathers, but VIs can work in any hazardous environments. When a new product is tested using expensive test equipments, it naturally raises the overhead cost. Employing VI there reduces the testing cost. They also increase the test safety. They do not get damaged and thus no need of replacements. This lessens the price of the final product for customers.

User friendliness The software used for VI is user friendly. In LabVIEW, new users can step through the dialogue boxes and quickly build a fully functioning DA application. LabVIEW will help define signal types, connections, and transducer equations before building the system. Thus, the learning curve is shortened significantly. More experienced developers can use the DAQ Wizards to prototype a system.



Most VI system contains a microprocessor, a data-acquisition unit or system, an I/O port, a display or a way of reporting the results and an analysis engine. Since most of the hardware is the same, only the front-end of the device needs to be changed to suit the equipment's purpose. With a personal computer, software could do the analysis after acquiring the needed data. Thus, the software could be written as such to specifically answer what is called for by the analysis. The hardware could be changed according to the design of the experiment, whether it will receive data from an apparatus or control it. Instead of using separate hardware front-ends, software could be written for measuring different quantities. Thus with sensors and appropriate software, any physical quantity can be acquired and measured in VI.

Some other applications of VI are data analysis, systems control, process automation, testing and calibration of instruments, telecommunications, semiconductor manufacturing, automotive testing, robotics, automation, embedded systems, etc.

4.6 CONCLUSION

The future of virtual instrumentation is promising. As such companies as Intel and Microsoft continue to usher in new technologies for advanced productivity and connectivity; virtual instrumentation's benefits will increase. Improvements in PC technology and VI hardware and software will make new applications possible. Companies like National Instruments are promoting VI to make it reach everyone. Quite sooner the traditional instrumentation will be completely moved inside the computer.

CHAPTER V

AUXILIARY COMPONENTS AND INTERFACING DEVICES

5.1 INTRODUCTION

This chapter mainly deals with the different hardware components that have been used for the calibration of energy meter. Exhaustive discussions about the auxiliary components have been incorporated in this chapter.

5.2 SENSOR

5.2.1 Introduction

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

5.2.2 **Current sensor:** current sensors based on open loop Hall Effect technology are also electronic transformers. They allow for the measurement of direct, alternative and impulse currents, with galvanic insulation between primary and secondary circuit.

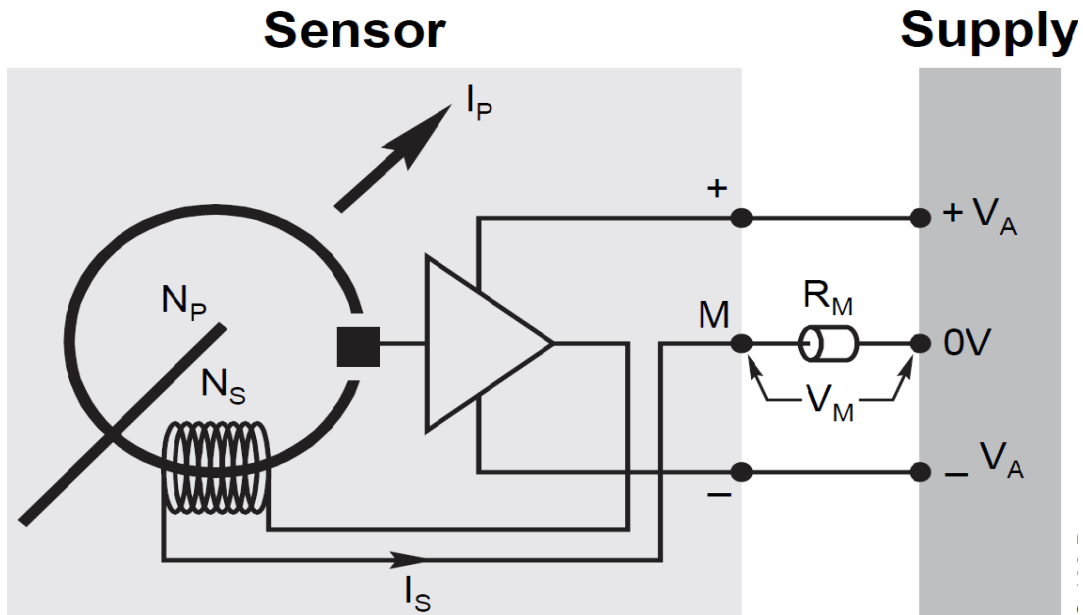


Fig 5.1 Internal circuit diagram of current sensor

The above figure represents the primary current I_P flowing across the sensor creates a primary magnetic flux. The magnetic circuit channels this magnetic flux. The hall probe placed in the airgap of magnetic circuit V_H proportional to this flux, which is itself proportional to the current

IP to be measured. The electronic circuit amplifies this hall voltage (VH) allowing it to be directly exploited by the operator as a secondary output voltage VM.

Current sensor EH050/100AP has been used with the figure as :

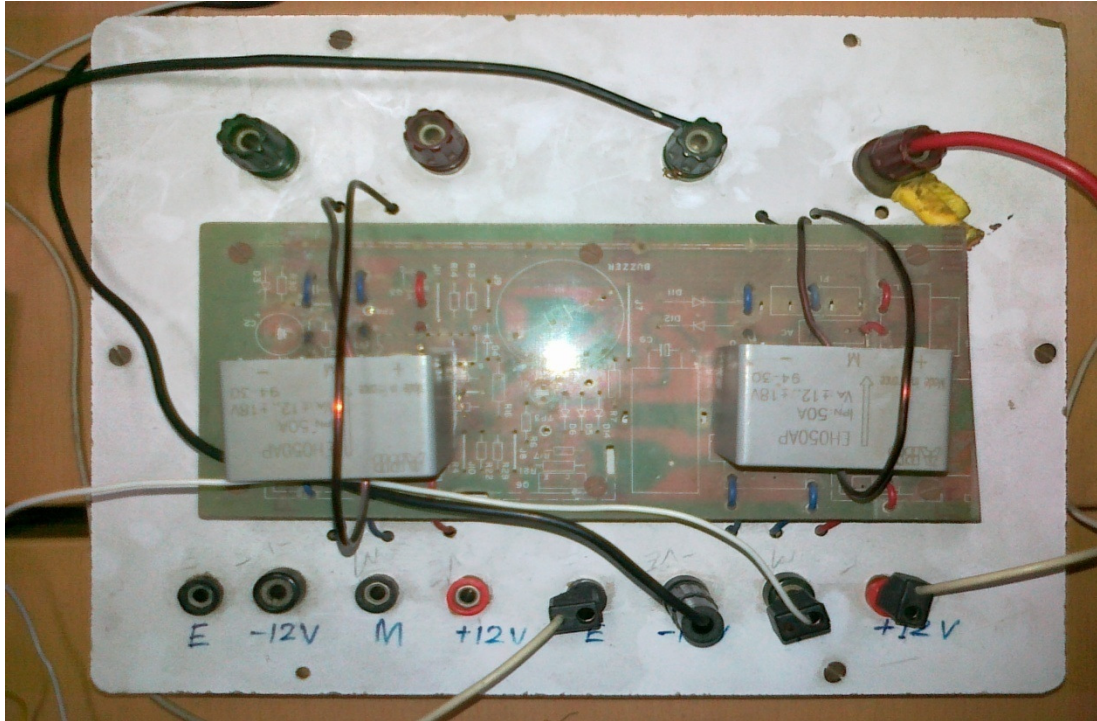


Fig 5.2 Current sensor

The above figure represents the two current sensors mounted on the same board. It is the five terminal devices with two input and one output. Rest of the two terminals has been used for the biasing of sensors. As it is marked on the board that +/- 12V is needed for the biasing purpose.

Common ground terminal- E.

Output terminal –M

Current sensor is connected in series with the load. The output of current sensor which is marked as M, is fed to the PCLD-8710 card for acquisition. An electrical characteristic of this current sensor is attached to appendix.

5.2.3 Voltage sensor

The voltage sensor uses electronic component. The voltage to be measured is directly applied to the terminal (as shown in fig by HT). The voltage is passed through an insulating amplifier and is then converted to a secondary output current I_s . This secondary current is electrically insulated from the primary voltage to which it is exactly proportional. The voltage sensor measures instantaneous values. In the same way as for current sensor, this secondary current I_s can be then

passed through a meaning resistance R_m is therefore also exactly proportional to the primary volt.

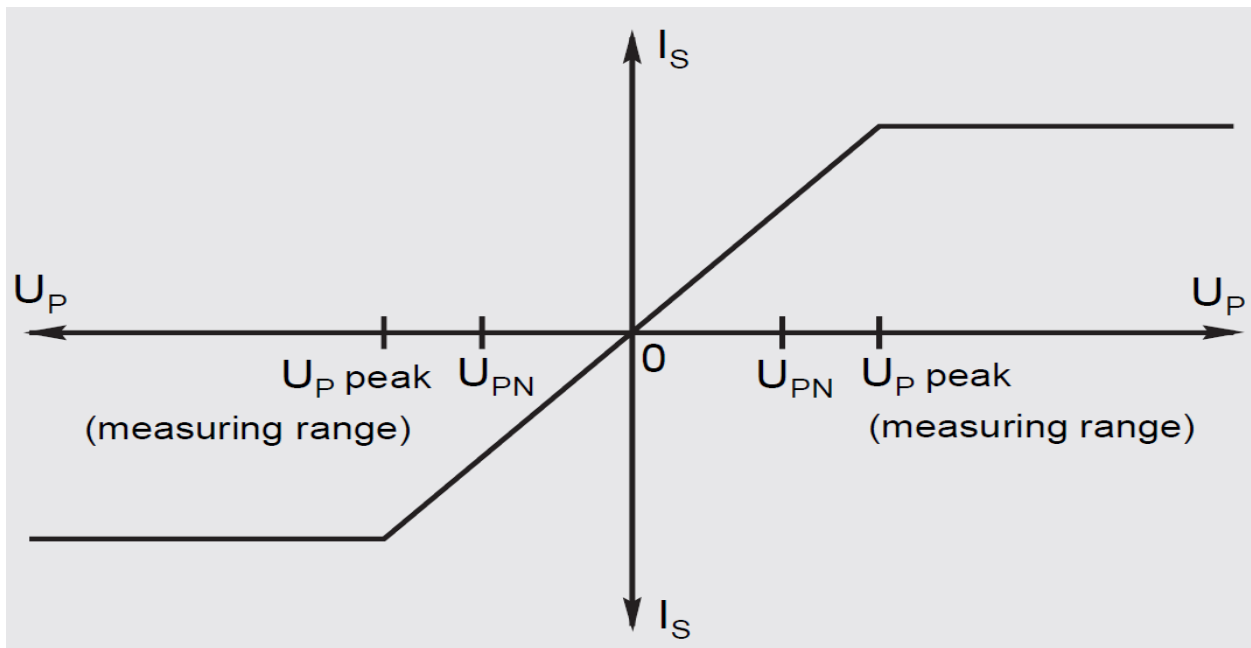
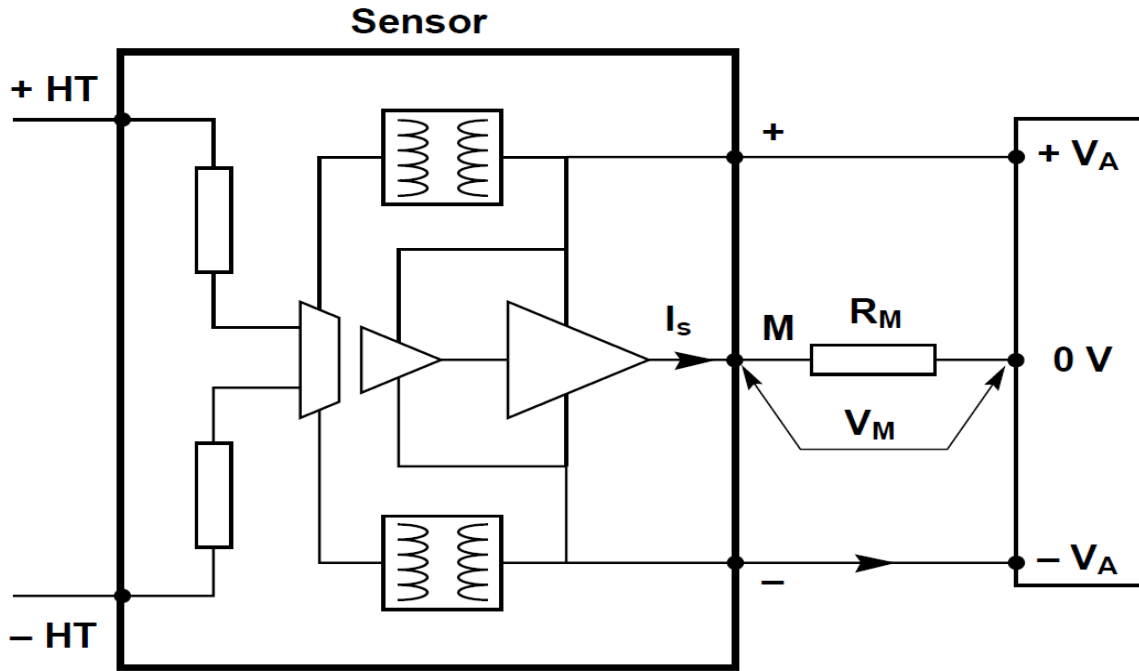


Fig 5.3 Circuit diagram and its input-output characteristic curve

Its characteristic curve represents the linear relation between secondary current and primary voltage when primary voltage is increased to nominal voltage.

Abbreviation:

Up-primary voltage

Upn-nominal primary voltage

Is-secondary current

Rm-resistance to be added to the measuring circuit

Va-sensor voltage supply

Vm-voltage measured



Fig 5.4 Voltage sensor with model EM010-9317 has been used in the project.

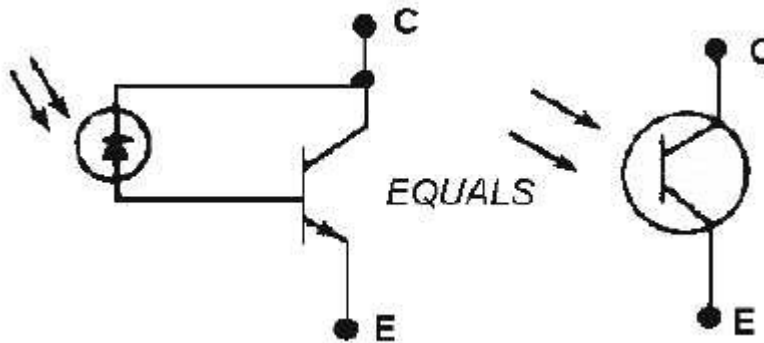
The above picture represents the two hall sensors mounted on the same board. Each voltage sensor is a three terminal device with two input and one output terminal. Two more terminal designated on the board by +12 and -12 volt is used for biasing the sensor. Output terminal is named as M and common ground is named as E. The output signal from the terminal M is fed to

the PCLD-8710 card for acquisition. Electrical characteristic of this model sensor has been incorporated in the appendix.

5.3 PHOTOTRANSISTOR

Phototransistor is a junction transistor whose base signal is generated by illumination of base. The emitter current, and hence collector current increases with intensity of light. In this way it regulated current or switches it on and off based on the intensity of light it is exposed to rather than an electric signal.

Symbolic representation of phototransistor



Above fig. illustrates the schematic symbol for various types of phototransistors. Phototransistors may be of the two terminal type, in which the light intensity on the photo diode alone determine the amount of conduction. They may be three terminal types, which have an added base lead that allows an electric bias to be applied to the base.

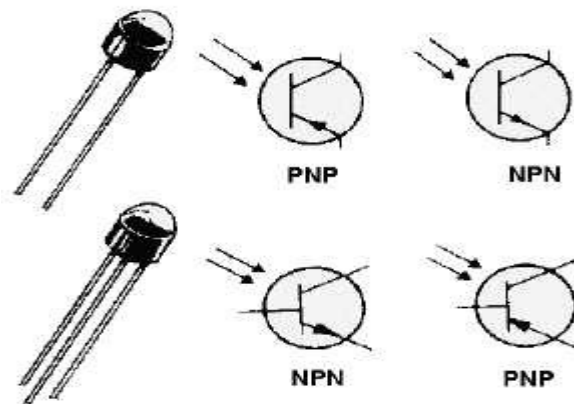


Fig 5.5 Picture showing two and three terminal type of phototransistor

Phototransistor Circuit configuration:

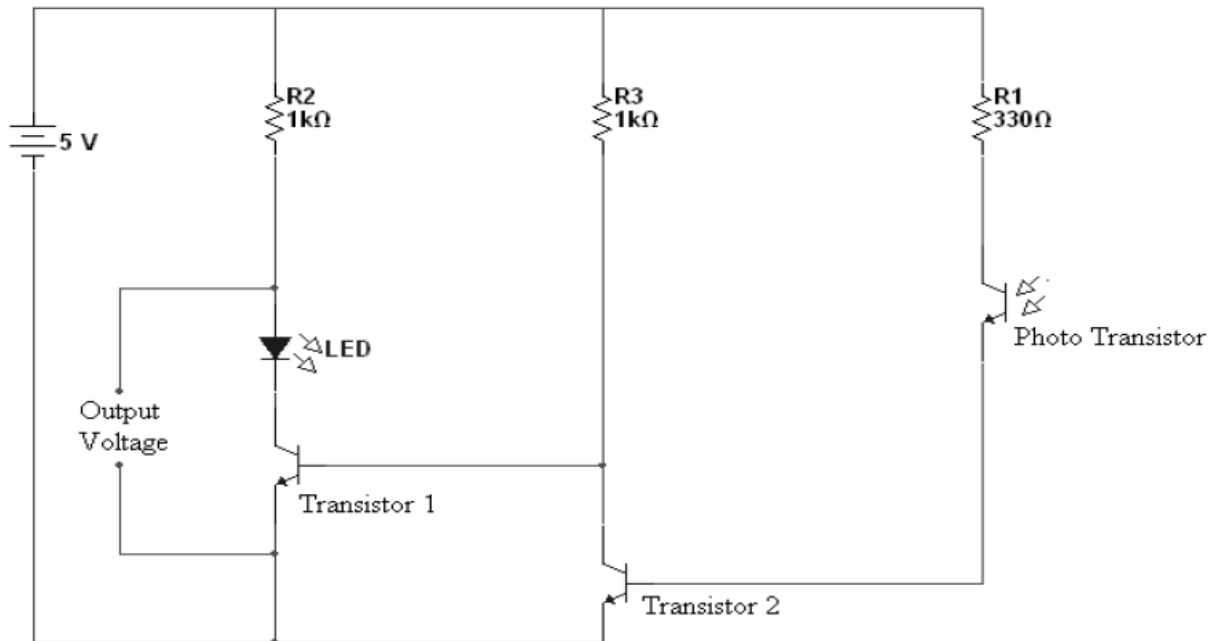


Fig.5.6 Circuit diag. of Phototransistor

The circuit constitutes of three resistances of value 330Ω , $1k\Omega$ and $1k\Omega$, two npn transistors (model no. BC-548), one phototransistor (model no. QSE114) and one constant voltage source of value 5V. This constant voltage source is used in the circuit for the biasing of transistors. The h_{fe} value of both the transistor is 100. Detailed characteristic of transistor is given in appendix.

Principle of operation:

When no light falls on the base lead of phototransistors, transistor 2 remains in cutoff region but transistor 1 is in the on state (saturation region). So the LED attached to the transistor1 glows as long as no light falls on phototransistor. As the light falls on the base lead of phototransistor, it gets turn on. As the emitter of phototransistor is connected to the base terminal of transistor2, so it makes the transistor2 to work in saturation region. So V_{CE} of transistor 2 will be approximately 0.2V which is less than 0.7V (V_{be}) needed to turn on transistor1. Hence transistor 1 remains in cutoff region. LED will not glow in this situation. So the output voltage is equal to 5V (approx.). Now it can be concluded that output voltage will attain high logic when base of phototransistor is illuminated by light otherwise, it will remain in low logic/voltage. Picture of phototransistor and its circuit configuration is shown below.

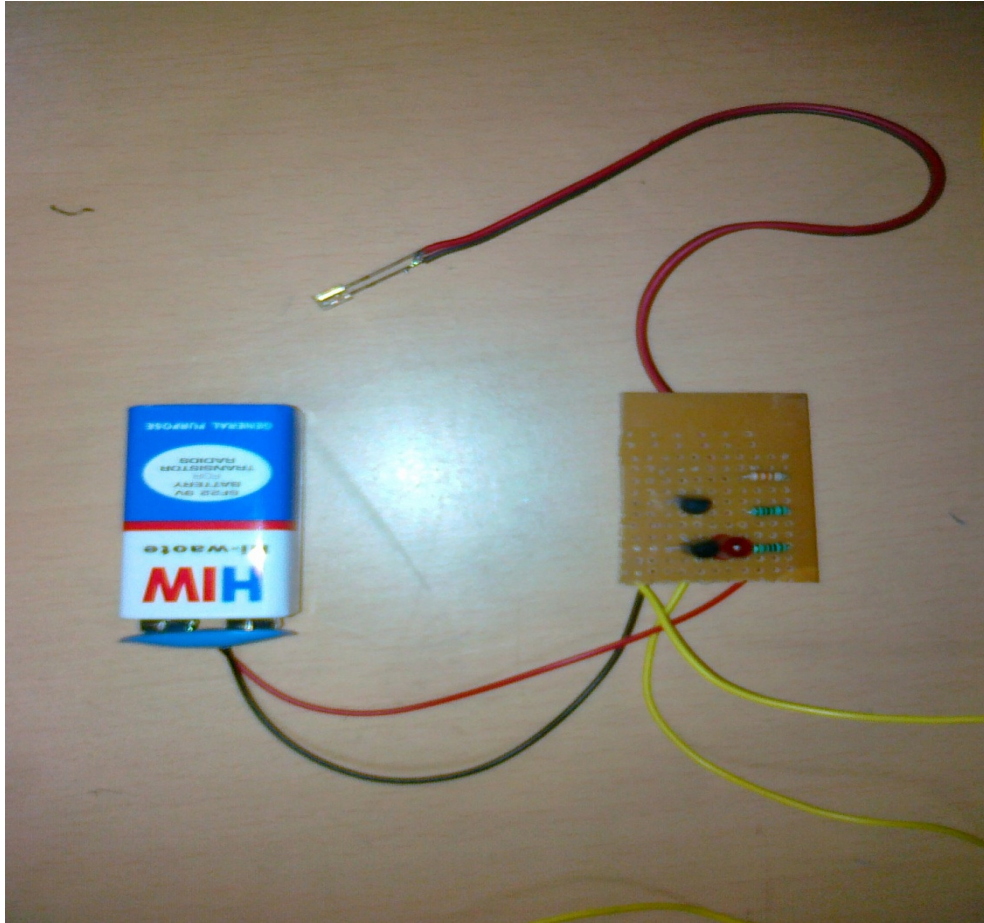
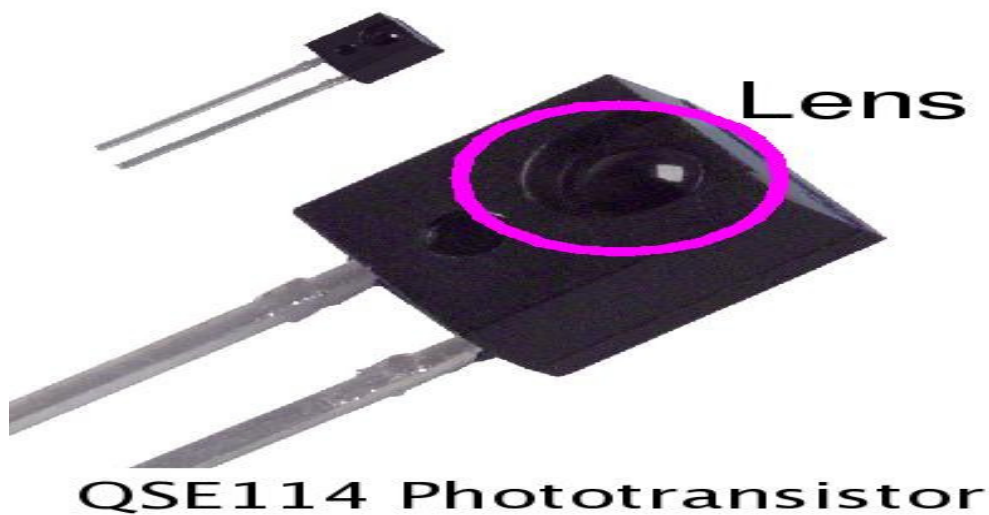


Fig 5.7 Picture of the phototransistor circuit

Model no QSE114 phototransistor has been used in the project. It is a two terminal device with lens type of phototransistor. Lens helps in converging the incident light to the base lead. Its specification is given in appendix. Its pictorial view is shown below:

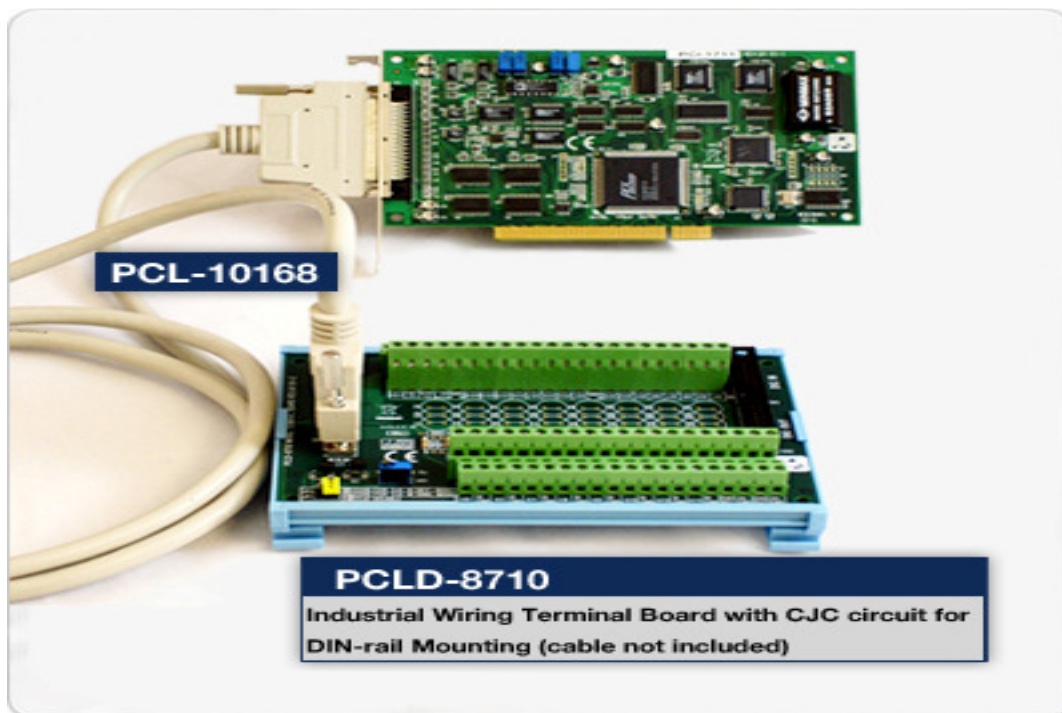


5.4 PCLD 8710 SCREW TERMINAL BOARD:

PCLD-8710 is designed to match multifunction cards with 68-pin SCSI-II connectors, such as PCI-1710/1710L/1710HG/1710HGL/1711/1711L/1716/1716L cards. This screw-terminal board also includes cold junction sensing circuitry that allows direct measurements from thermocouple transducers. Together with software compensation and linearization, every thermocouple type can be accommodated. Due to its special PCB layout, we can install passive components to construct your own signal-conditioning circuits. So you can easily construct a low-pass filter, attenuator or current shunt converter by adding resistors and capacitors onto the board circuit pads.

5.5 WIRING CABLE PCL-10168 :

PCL-10168: shielded cable which is specially designed for PCI-1711 card to provide high resistance to noise. To achieve better signal quality, the signal wires are twisted in such a way as to form a “twisted – pair cable “, reducing cross - talk and noise from other signal sources. Furthermore, its analog and digital lines are separately sheathed and shielded to neutralize EMI/EMC problems. Hence the communication between PCI-1711 Card and PCLD-8710 is through wiring cable PCL-10168 which is as shown in below figure but practically PCI-1711 Multi Function Card will be inserted in PC therefore it cannot be viewed .



5.6 PCI-1711 MULTI FUNCTION CARD

PCI-1711 powerful, but low-cost multifunction cards for the PCI bus. PCI-1711 comes with 2 analog output channels. Thus, PCI-1711L represents a cost saver for those that do not need analog output.

Features

- 16-ch single-ended analog input
- 12-bit A/D converter, with up to 100 kHz sampling rate
- Programmable gain
- Automatic channel/gain scanning
- Onboard FIFO memory (1,024 samples)
- Two 12-bit analog output channels (PCI-1711 only)
- 16-ch digital input and 16-ch digital output
- Onboard programmable counter



Fig 5.8 PCI-1711 Multi Function Card

CHAPTER-VI

SYSTEM INTEGRATION FOR THE CALIBRATION OF ENERGY METER

6.1 INTRODUCTION

This chapter deals with the integration of all the components, hardware and software, require for the calibration purpose.

6.2 EXPERIMENTAL SETUP

Hardware connections: Individual auxiliary component (hardware) has been discussed in the preceding chapters with detailed study. In order to achieve the require task (calibration of energy meter), these auxiliary components along with the interfacing devices is integrated in a certain manner shown below in the form of block representation.

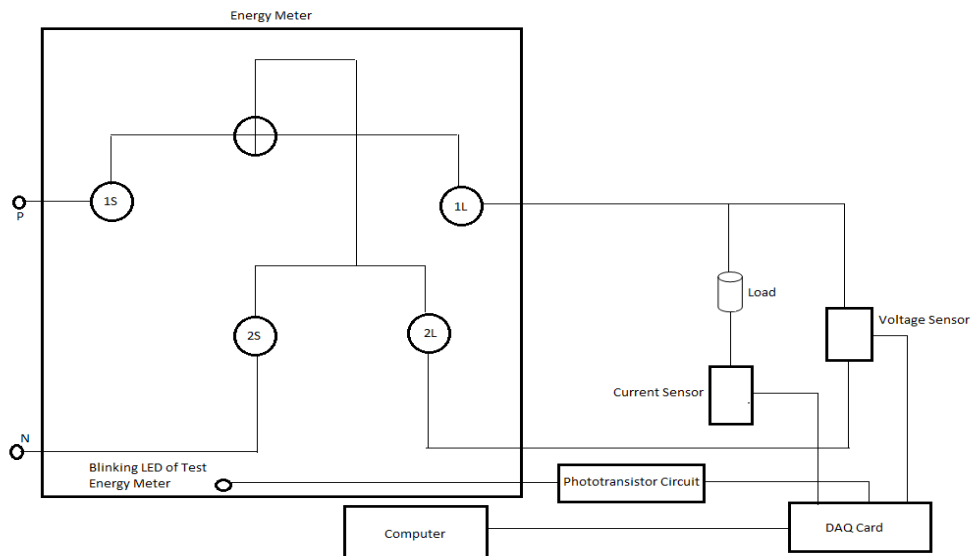


Fig 6.1 Block diagram: hardware connection

1S, 2S, 1L, 2L- TERMINALS OF ENERGY METER

C.S-CURRENT SENSOR

V.S-VOLTAGE SENSOR

The above figure represents the circuit diagram for the calibration of energy meter. The voltage sensor is connected across the input voltage and the current sensor is connected in series with load. Outputs of voltage and current sensor is accessed through DAQ card, which converts these analog signal (a.c signal generated by sensor) into digital so that these digital signals can be acquired by the computer.

The purpose of using phototransistor in the project is the automated calibration. The test energy meter does not display the fractional energy consumed, this makes the calibration more inaccurate and time consuming, as the shortest unit(1unit=1Kwh) that can be displayed by the test energy meter is one unit (though some of the energy meter shows the fractional unit). At the same time counting the number of blinks of LED, mounted on the front face of the energy meter (as the test energy meter is rated with 6400 impulse/unit), over a certain span of time demands human involvement. Hence accuracy of calibration is deteriorated. So in order to avoid human involvement and make a automated calibration, counting of LED blinks over a span of time is done with the help of LAB VIEW. So, a need to acquire a impulse signal arises. Phototransistor incorporated in circuit configuration solves our problem. As the blinking frequency of light falling on phototransistor will be same as that of the frequency of output voltage generated of the circuit. Hence this circuit acts as a facilitator, as it converts the light signal to electrical signal which can be acquired by DAQ card. By doing the proper designing in LAB VIEW, the reading of test energy meter is calculated and displayed on the front panel of VI instrument. In this way test energy meter connected across mains will start indicating the energy consumed in the circuit and this energy consumed can be observed through LAB VIEW with the help of phototransistor circuit. At the same time the virtual energy meter designed with the help of LAB VIEW software (which acts here as a standard instrument) also indicates the energy consumed. Difference of two readings (one taken of test energy meter and other of virtual energy meter designed in LAB VIEW) give us error and hence percentage error. In this way calibration is performed.

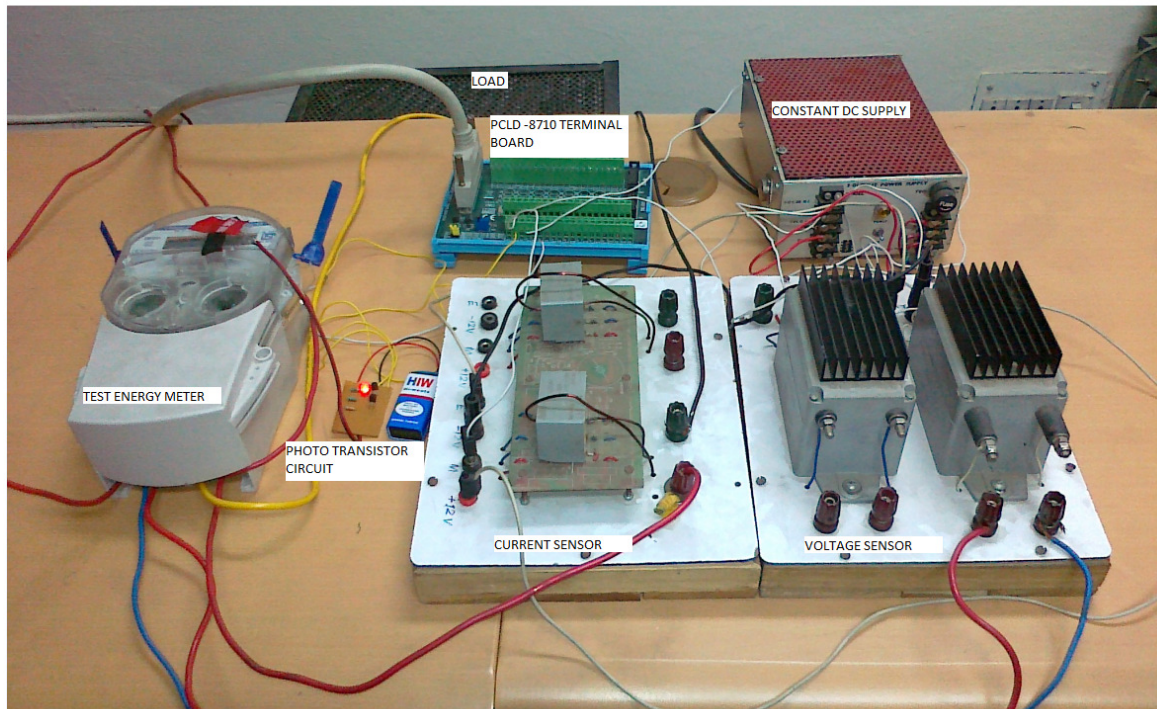


Fig 6.2 Hardware connections

The above picture represents the sensors constant DC supply, load and interfacing device as PCLD-8137. The shown connection is in the same manner as represented by the block diagram of hardware connections.

6.3 PROGRAMMING IN LAB VIEW

The programming in LAB VIEW is represented by the different block diagram connected as per the requirement. Different blocks used in LAB VIEW while designing the virtual energy meter are as follows:

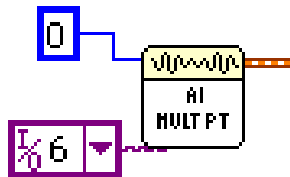
- 1. Analog Inputs:** Analog inputs block is a kind of subVI which outputs the voltage or the signal whatever is connected to the DAQ device, corresponding to the port number specified in the subVI. Further details of the block are as follows:

Inputs to Block:

- a. Device No.:** The device no. specifies the index of the DAQ device by the user. In case of multiple devices used for the data acquisition, this helps in selecting a particular DAQ device.

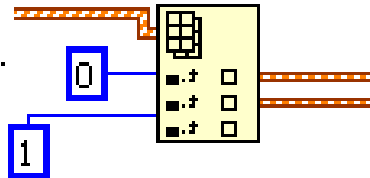
- b. Port no.:** This input specifies the input port from which the data has to be fed in the computer from DAQ device. In case of multiple input signals the DAQ device sequentially scans the input ports, for which the sampling frequency of the device determines the time interval between two successive scans and feed these to the Lab VIEW. The input ports are written in the order in which they has to feed be in Lab VIEW.
- c. Output:** The signal waveform which is fed into the DAQ device can be drawn to front Panel for display purpose or can be processed further to get some other relevant information. In case of multiple input signals, the waveforms are in the form of array and can be sequentially drawn according to the port no. and the index specified to the array.

Figure for the block is shown below,



- 2. Index Array:** Index array block, in general, outputs an element from an array according to the index specified to the block. Further details of the block are as follows:
 - a. Input Array:** This terminal is fed with the array whose element is to be extracted for further processing.
 - b. Index:** This terminal specifies the index corresponding to the array i.e. which element is to be extracted from the array. This array indexes are started from the 0 to n-1 for an n- element array.
 - c. Outputs:** According to the indexes at the input terminals the output terminals are selected. Each output terminal produces the element of the array in accordance of the indexes selected.

Figure for the block is shown below,



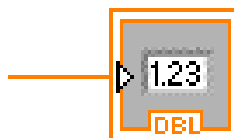
3. Waveform Graph: Waveform graph is a front panel block which produces the waveform with respect to the time at the front panel screen. It is very helpful for the user if the signal is shown in the form of a waveform, as he can easily interpret the form of the signal whether sinusoidal, square, and rectangular or any arbitrary signal. Further details of the block are as follows:

- a. Input Waveform:** This terminal is fed with the waveform signal whose graph is to be shown at the front panel. Since this is a front panel block used for the display purpose, the input terminal is the only terminal for the block.

Figure for the block is shown below,



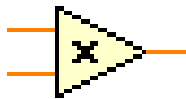
4. Numerical Display: It is also a display block used for the purpose of displaying any numerical value to the user at the front panel. The block has only one input terminal which is used for supplying the block with the value to be displayed. The block is very helpful in displaying the variables which vary very slowly or some constants which can or cannot be user defined. Figure for the block is shown below,



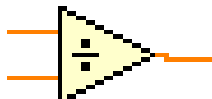
5. Math Functions: The math functions are used for the general purpose calculative procedure, such as in formulating an expression for the energy consumed, which has very basic functions such as addition, multiplication, division. Besides that some trigonometric functions has also been used in the programming for this work, as power factor has been calculated, so a **cosine function block** has also been used.

a. Addition: The block has two input terminals for the input variables which are to be added. It also has one output which is the result of the addition.

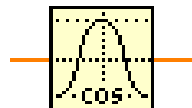
b. Multiplication: This block also has two input terminals for the input variables which are to be multiplied. It has one output terminal which produces the result of the multiplication. Figure for the block is shown below,



c. Division: This block also has two input terminals for the input variables which are to be divided. It has one output terminal which produces the result of the division. Figure for the block is shown below,

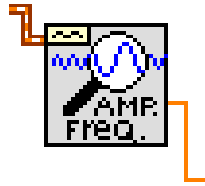


d. Cosine: The block has only one input terminal and one output terminal which are for the argument and the result respectively. The block computes the cosine value for the radian value of the input. Figure for the block is shown below,



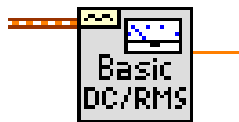
6. Single Tone Extraction: This block is used for the frequency related measurement of the signal. There is one input terminal for the input signal and multiple output terminals

which produce the information of the signal such that what is the frequency of the signal, phase of the signal etc. Figure for the block is shown below,



7. **Waveform Measurement:** This block is used for the amplitude related measurement of the signal. There is one input terminal for the input signal and multiple output terminals which produce the information of the signal such that what is the peak amplitude of the signal, DC value of the signal, RMS value of the signal, Average value of the signal etc. The values produced by the block can be used for further processing. The very basic advantage of using this block is that, one need not to develop the programming for calculating the different values of the signal, it becomes very easy for the user to draw the value of the signal by simply placing the block, connecting the terminals of the blocks to appropriate places, and just getting the readings.

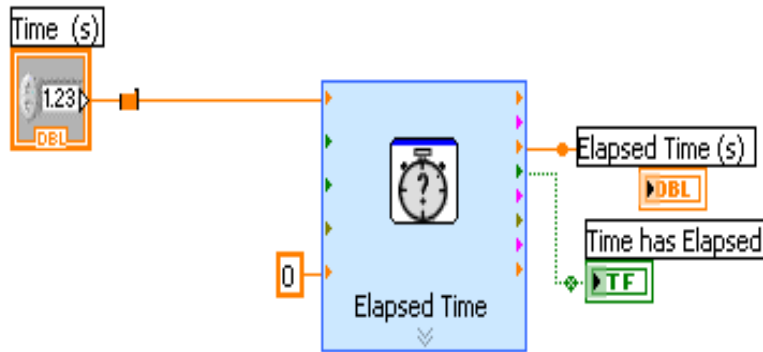
Figure for the block is shown below,



8. **Elapsed Time:** This block has five input terminals, in which two have been used for the work. The two terminal connected are initial time and the Final time. One can use this block as a countdown timer. The initial and the final time are fed to the block, as the program runs, the block counts the seconds passed and compares with the final time fed to it and according to it produces a Boolean output which becomes TRUE as soon as the final time is reached. This Boolean output can be used to trigger a condition which stops or starts a VI according to condition supplied to it.

The block has multiple outputs which includes, **Elapsed Time** terminal which produces the seconds which has been passed since the VI has been started, and Boolean output

indicating a TRUE or FALSE condition depending on the condition whether the final time has been passed or not. Figure for the block is shown below,



The function of different blocks has been discussed above. Now these blocks are assembled as shown in the diagram below (VI block diagram).

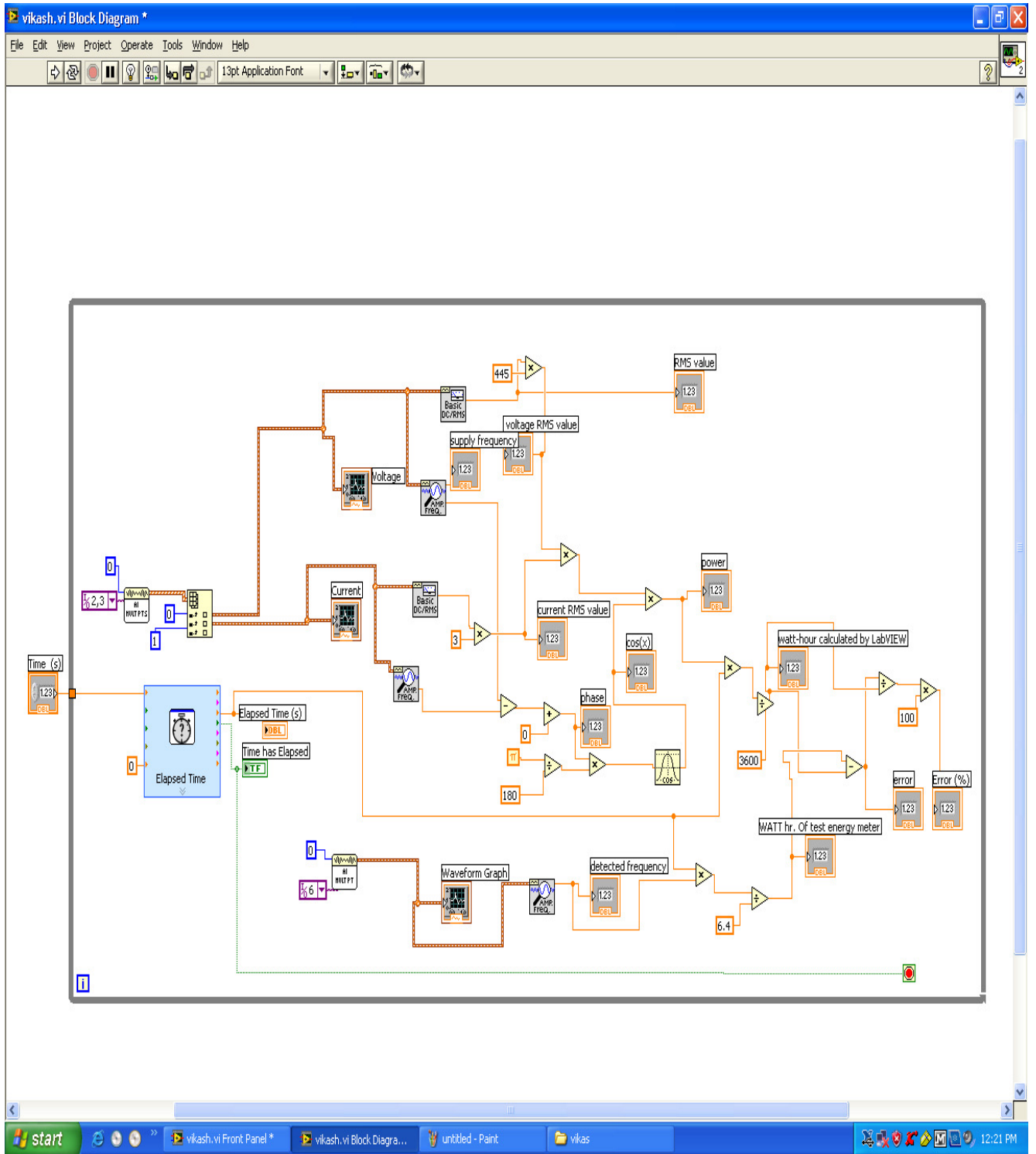


Fig 6.3 VI block diagram

Explanation: above block diagram shows the way virtual energy meter is designed in Lab VIEW and hence calibrated. (AI MULTPTS) block in the above figure, acquire voltage and current signal. (r.m.s) block calculates the r.m.s value of the acquired signal. Power is given by

$P=VI\cos\Phi$ where V and I is the r.m.s value of voltage and current signal respectively. Φ is the phase difference between voltage and current signal.

Energy=power* time

In order to calculate the power, one requires r.m.s value of voltage and current, along with this phase difference is also required. Block named as (basic D.C/r.m.s) calculate the r.m.s value of acquired voltage and current signals. The block (amp/freq) calculates the phase of the input current /voltage signal. The output of these blocks (separates for current and voltage signal) is subtracted with the help of (subtraction block). Cosine of this phase difference solves our purpose. Cos block represented in above block diagram calculates $\cos \Phi$. The above calculated r.m.s value of current and voltage and $\cos \Phi$ is needed to be multiplied. Hence we get the calculated power. To have the value of energy consumed over a certain span of time (elapsed time block has been used). Multiplication of output of elapsed time block with above calculated power gives the energy consumed. Energy consumed is divided by 3600 to give watt-hour. This displayed reading is the reading of virtual energy meter formed in LAB VIEW.

In order to have the automated calibration the output of phototransistor circuit is fed to the DAQ card. This signal is also acquired by (AI MULTPTS) block as shown in figure. Block (amp/freq) calculates the frequency of this input signal. Its frequency is multiplied by the elapsed time to obtain the number of pulse in a given time. Then, this pulse count is divided by 6.4 with the help of divider block. As the test energy meter is rated as 6400 impulse/unit, so reading of test energy meter is given by= [no. of pulse count multiplied by 6.4]. So a division of 6.4 has been taken into account above. The output of this division block display the energy consumed by the test energy meter. For the calibration purpose the difference between the two readings: one from the virtual energy meter designed in Lab VIEW and other, the reading of test energy meter (which is also automated with the help of Lab VIEW, discussed above) is taken into account. Subtraction block is used for this purpose. Its output will be error. Similarly percentage error is also calculated. In this way Lab VIEW facilitates to have the automated calibration.

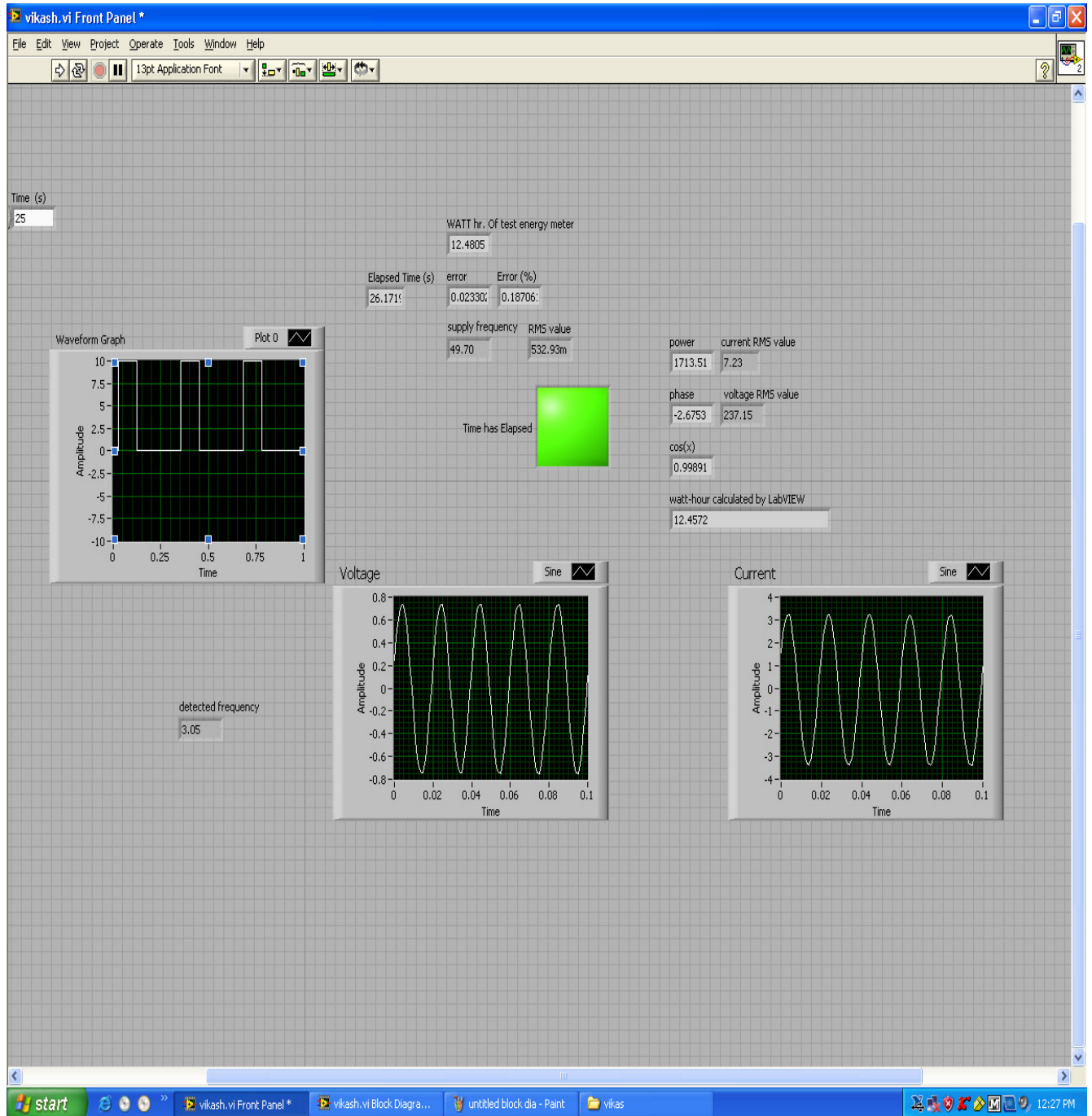


Fig 6.4 Front panel diagram

Front panel shows the voltage and current waveform along with its r.m.s value and the input signal acquired from the phototransistor circuit. Its detected frequency is also shown. V_{rms} , I_{rms} , power, phase, cosine of phase (power factor), time elapsed, watt-hour calculated by test energy meter and watt-hour of virtual energy meter is also shown on the front panel. Error and percentage error shown in the front panel give us the required result for the calibration. Note that in order to achieve the best result, constant voltage supply (A.C) is required.

As $W=P.t$

Where W is energy, P-power and t-time. This equation holds true as long as P is constant. So the use of voltage stabilizer is recommended.

6.4 OSCILLOSCOPE:

An **oscilloscope** (abbreviated sometimes as **scope** or **O-scope**) is a type of electronic test equipment allows signal Voltage to be viewed, usually as a two-dimensional graph of one or more electrical potential difference (vertical(Y) axis) plotted as a function of time or of some other voltage (horizontal(x) axis). Although an oscilloscope displays voltage on its vertical axis, any other quantity that can be converted to a voltage can be displayed as well. In most instances, oscilloscopes show events that repeat with either no change or change slowly. The oscilloscope is one of the most versatile and widely-used electronic instruments. Oscilloscopes are commonly used when it is desired to observe the exact wave shape of an electrical signal. In addition to the amplitude of the signal, an oscilloscope can show distortion and measure frequency, time between two events (such as pulse width or pulse rise time), and relative timing of two related signals. To verify whether acquired signal is matching with the input signal oscilloscope is used.

6.5 PICTORIAL REPRESENTATION OF EXPERIMENTAL SETUP

Figure below represents the hardware and software components required for the assemble of complete experimental setup.

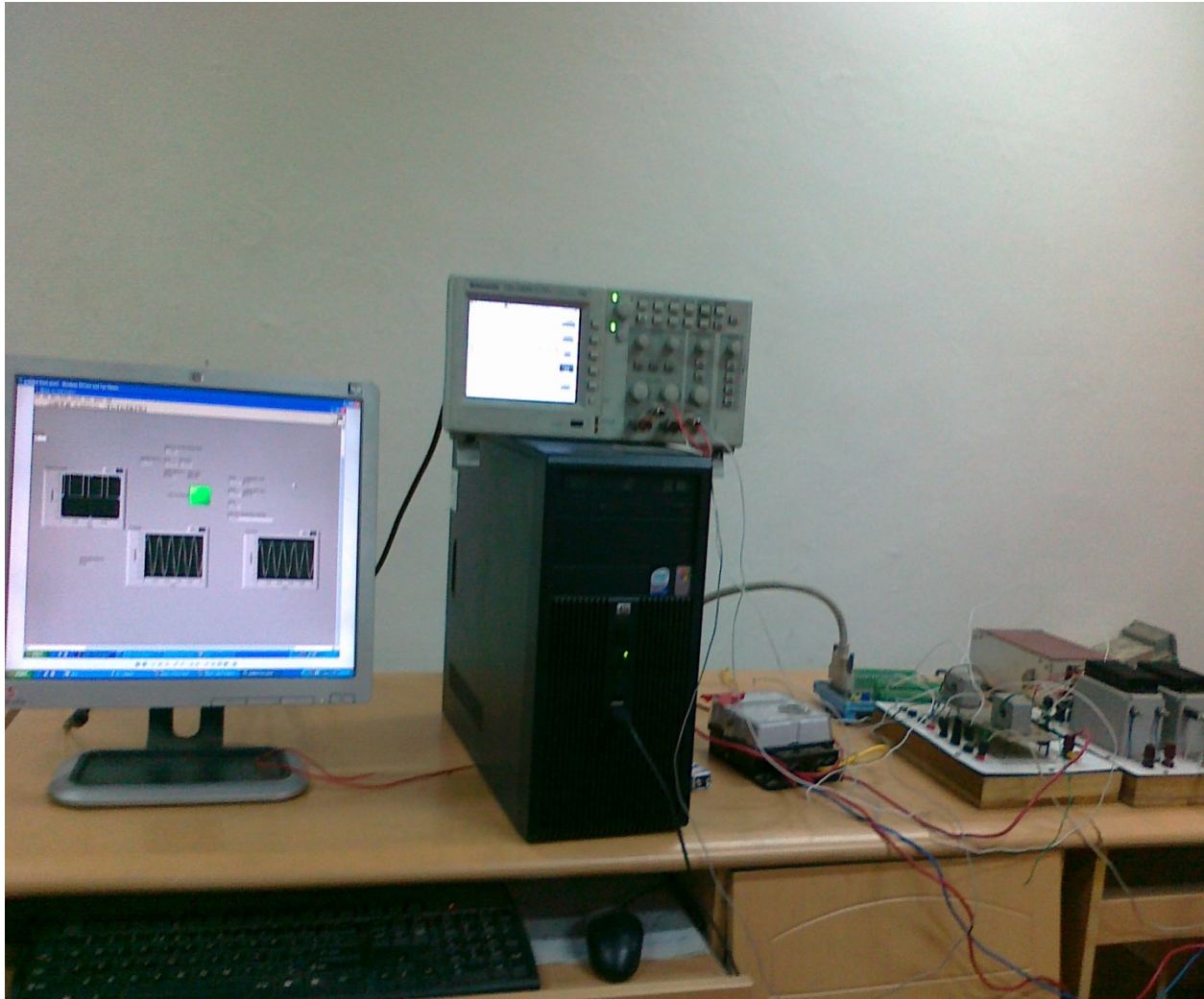


Fig.6.5 picture of experimental setup

6.6 CONCLUSION:

Calibration of test energy meter with ADVANTECH DAQ Card using Lab VIEW software is done successfully.

CHAPTER-VII

RESULTS AND DISSCUSSION

Calibration requires two reading, one from standard instrument and another reading from test instrument. Difference between two readings gives error. In present context error is given by:

$$\text{ERROR} = (\text{Reading of Lab VIEW} - \text{Reading of test Energy meter})$$

$$\% \text{ ERROR} = \frac{\text{ERROR}}{(\text{reading of Lab VIEW})} * 100$$

Two tests are performed for the calibration of energy meter:

1. No load test: 110% of rated voltage is applied across the test energy meter at no load.
2. Full load test is conducted at
 - a) Unity power factor load
 - b) 0.5 lag power factor load
 - c) 0.5 lead power factor load

OBSERVATION:

1. No load test is conducted and no creeping is found.
2. Full load test is conducted at different power factor and it is represented in the observation table below.

Unity Power factor load:

Observation table 1

$I_L=4.88 \text{ A}$, $V=242\text{V}$, $\cos\Phi=0.999$

S.no	Time(s)	Reading with LabVIEW(Watt-hour)	Reading with Electronic energy meter(Watt-hour)	Error	%Error
1	15	4.91082	4.93528	0.02446	0.49
2	30	9.82260	9.89305	0.07045	0.71
3	45	14.73247	14.76803	0.03556	0.64
4	60	19.66330	19.72886	0.06556	0.33
5	75	24.55412	24.65368	0.09956	0.40

AUTOMATED CALIBRATION OF ELECTRONIC ENERGY METER USING LabVIEW

6	90	29.46432	29.58980	0.12548	0.42
7	105	34.37577	34.56260	0.15688	0.45

Observation table 2

$I_L=7.39$ A, $V=242$ V, $\cos\Phi=0.999$

S.no	Time(s)	Reading with LabVIEW(Watt-hour)	Reading with Electronic energy meter(Watt-hour)	Error	%Error
1	10	4.9189	4.95772	0.03882	0.78
2	20	9.82521	9.87028	0.04507	0.45
3	35	17.7431	17.8291	0.0860	0.48
4	40	19.8039	19.8739	0.0700	0.35
5	45	22.863	22.9538	0.0907	0.39
6	50	24.7798	24.9094	0.1296	0.52
7	60	29.8945	30.0433	0.1488	0.49

Observation table 3

$I_L=9.33$ A, $V=242$ V, $\cos\Phi=0.999$

S.no	Time(s)	Reading with LabVIEW(Watt-hour)	Reading with Electronic energy meter(Watt-hour)	Error	%Error
1	15	9.38893	9.42528	0.03635	0.38
2	30	18.77786	18.8348	0.05699	0.30
3	45	28.1668	28.27344	0.10664	0.37
4	60	37.4327	37.6149	0.18226	0.48
5	75	46.8446	47.0451	0.20056	0.42
6	90	56.336	56.5900	0.25684	0.45
7	105	65.7225	66.0090	0.28653	0.43

0.5 Power factor lagging:**Observation table 4**

$I_L=7.64$ A, $V=242$ V, $\cos\Phi=0.53$ (lag)

S.no	Time(s)	Reading with LabVIEW(Watt-hour)	Reading with Electronic energy meter(Watt-hour)	Error	%Error
1	15	4.08294	4.10862	0.02568	0.53
2	30	8.16588	8.2225	0.05662	0.69

AUTOMATED CALIBRATION OF ELECTRONIC ENERGY METER USING LabVIEW

3	45	12.24883	12.3011	0.05228	0.42
4	60	16.3317	16.39754	0.06584	0.40
5	75	20.4147	20.4994	0.08471	0.41
6	90	24.4973	24.639	0.14254	0.58
7	105	28.5806	28.7331	0.15256	0.53

0.5 Power factor leading:**Observation table 5** $I_L=9.36$ A, $V=237$ V, $\cos\Phi=0.58$ (lead)

S.no	Time(s)	Reading with LabVIEW(Watt-hour)	Reading with Electronic energy meter(Watt-hour)	Error	%Error
1	15	5.36094	5.3987	0.03776	0.70
2	30	10.73288	10.78848	0.05560	0.51
3	45	16.10292	16.14848	0.4556	0.28
4	60	21.34476	21.43726	0.09250	0.43
5	75	26.8048	26.98775	0.18305	0.68
6	90	32.12564	32.31127	0.18563	0.57
7	105	37.51382	37.75600	0.24662	0.64

Graphs: Based on the above observation table, graphs between the % Error and time has been plotted below. Note the time variation of % error with respect to time. This variation is mainly due to small fluctuation in input supply voltage.

RESULT:

1. No creeping is found in the test energy meter.
2. The reading of the test energy meter has an error of 0.48%.

APPENDIX

ELECTRICAL CHARACTERISTICS OF CURRENT SENSOR

Electrical characteristics

Type		EH 050 AP	EH 100 AP
Nominal primary current I_{PN} (A r.m.s.)		50	100
Measuring range (A d.c.)		± 240	± 240
with V_A & R_M max.		$\pm 12\text{ V} \ \& \ 10\ \Omega$	$\pm 12\text{ V} \ \& \ 10\ \Omega$
with V_A & R_M max.		$\pm 18\text{ V} \ \& \ 30\ \Omega$	$\pm 18\text{ V} \ \& \ 30\ \Omega$
Overload (\hat{A})		$\pm 240 - 1\text{ min/h}$	$\pm 240 - 1\text{ min/h}$
Turns ratio (N_P/N_S)		1/1000	1/1000
Secondary current I_{SN} at I_{PN} (mA)		50	100
Accuracy max. at I_{PN} (0 ... +70 °C) (%)		± 1	± 1
Residual current I_{SO} (+25 °C) (mA)		± 0.25	± 0.4
Linearity / I_S better than		10^{-3}	10^{-3}
Thermal drift / I_{SN} (1°C)		$< 10^{-4}$	$< 10^{-4}$
Delay time (μs)		< 1	< 1
d_i/d_t correctly followed (A/ μs)		> 50	> 50
Bandwidth (-1 dB) (kHz)		100	100
No-load current I_{AO} (mA)		10 with $V_A = \pm 12\text{ V}$	
(mA)		15 with $V_A = \pm 18\text{ V}$	
Secondary resistance (+70 °C) (Ω)		30	30
Dielectric strength P/S (kV r.m.s. 50Hz-1min)		3	3
Supply voltage V_A (V)		± 12 to ± 18 ($\pm 5\%$)	
Minimum measuring resistance (+ 70 °C) (Ω)		0 with $V_A = \pm 12\text{ V}$	0 with $V_A = \pm 12\text{ V}$
(Ω)		0 with $V_A = \pm 18\text{ V}$	12 with $V_A = \pm 18\text{ V}$
- by unidirectional use (Ω)		0 with $V_A = +24\text{ V}$	62 with $V_A = +24\text{ V}$

ELECTRICAL CHARACTERISTICS OF VOLTAGE SENSOR

Electrical characteristics of calibrated EM 010 sensors

References	Dielectric strength P/S kV r.m.s. 50 Hz 1 min		Primary nominal voltage	Measuring range (50 s/h)	N _p /N _s	R _p	R _s
	6	12				(kΩ)	(Ω)
EM010-9237	x		200	± 300	4000/2000	8	60
EM010-9238	x		400	± 600	4000/2000	16	60
EM010-9320	x		500	± 750	5000/2000	25	60
EM010-9239	x		600	± 900	10000/2000	60	60
EM010-9240	x		750	± 1125	7500/2000	56	60
EM010-9371		x	1000	± 1500	15000/2000	150	60
EM010-9241	x		1200	± 1800	12000/2000	144	60
EM010-9317		x	1500	± 2250	15000/2000	225	60
EM010-9318		x	2000	± 3000	20000/2000	400	60
EM010-9319		x	3000	± 4500	30000/2000	900	60
EM010-9394		x	4200	± 8000	30000/1250	2000	25
EM010-9354		x	5000	± 8000	20000/1000	2000	20

SPECIFICATION OF PHOTOTRANSISTOR QSE-114:

ABSOLUTE MAXIMUM RATINGS (T _A = 25°C unless otherwise specified)			
Parameter	Symbol	Rating	Unit
Operating Temperature	T _{OPR}	-40 to +100	°C
Storage Temperature	T _{STG}	-40 to +100	°C
Soldering Temperature (Iron) ^(2,3,4)	T _{SOL-I}	240 for 5 sec	°C
Soldering Temperature (Flow) ^(2,3)	T _{SOL-F}	260 for 10 sec	°C
Collector Emitter Voltage	V _{CE}	30	V
Emitter Collector Voltage	V _{EC}	5	V
Power Dissipation ⁽¹⁾	P _D	100	mW

SPECIFICATION OF NPN TRANSISTOR(BC548,B):

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

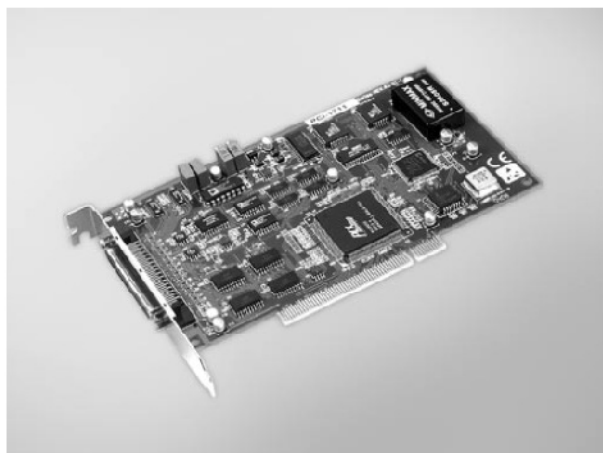
Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector–Emitter Breakdown Voltage ($I_C = 1.0\text{ mA}$, $I_B = 0$)	BC546	$V_{(BR)CEO}$	65	—	—	V
	BC547		45	—	—	
	BC548		30	—	—	
Collector–Base Breakdown Voltage ($I_C = 100\ \mu\text{A}$)	BC546	$V_{(BR)CBO}$	80	—	—	V
	BC547		50	—	—	
	BC548		30	—	—	
Emitter–Base Breakdown Voltage ($I_E = 10\ \mu\text{A}$, $I_C = 0$)	BC546	$V_{(BR)EBO}$	6.0	—	—	V
	BC547		6.0	—	—	
	BC548		6.0	—	—	

ON CHARACTERISTICS

DC Current Gain ($I_C = 10\ \mu\text{A}$, $V_{CE} = 5.0\text{ V}$)	BC547A/548A	h_{FE}	—	90	—	—
	BC546B/547B/548B		—	150	—	
	BC548C		—	270	—	
(I _C = 2.0 mA, V _{CE} = 5.0 V)	BC546	110	—	450		
	BC547	110	—	800		
	BC548	110	—	800		
	BC547A/548A	110	180	220		
	BC546B/547B/548B	200	290	450		
	BC547C/BC548C	420	520	800		
(I _C = 100 mA, V _{CE} = 5.0 V)	BC547A/548A	—	120	—		
	BC546B/547B/548B	—	180	—		
	BC548C	—	300	—		
Collector–Emitter Saturation Voltage ($I_C = 100\text{ mA}$, $I_B = 5.0\text{ mA}$)		$V_{CE(sat)}$	—	—	0.3	V
Base–Emitter Saturation Voltage ($I_C = 100\text{ mA}$, $I_B = 5.0\text{ mA}$)		$V_{BE(sat)}$	—	—	1.0	V
Base–Emitter On Voltage ($I_C = 2.0\text{ mA}$, $V_{CE} = 5.0\text{ V}$) ($I_C = 10\text{ mA}$, $V_{CE} = 5.0\text{ V}$)		$V_{BE(on)}$	0.55	—	0.7	V
			—	—	0.77	

PCI-1711/L

**Entry-level 100 kS/s, 12-bit, 16-ch
PCI Multifunction Card**



Features

- 16 ch single ended analog input
- 12-bit A/D converter, with up to 100 kHz sampling rate
- Programmable gain
- Automatic channel/gain scanning
- Onboard FIFO memory (1,024 samples)
- Two 12-bit analog output channels (PCI-1711 only)
- 16 ch digital input and 16 ch digital output
- Onboard programmable counter

Introduction

PCI-1711 and PCI-1711L are powerful, but low-cost multifunction cards for the PCI bus. PCI-1711 comes with 2 analog output channels, while the PCI-1711L doesn't. Thus, PCI-1711L represents a cost saver for those that do not need analog output.

Specifications

Analog Input

- Channels 16 single-ended
- Resolution 12 bits
- Max. Sampling Rate 100 kS/s
- FIFO Size 1,024 samples
- Overvoltage Protection 30 V_{p-p}
- Input Impedance 2 M Ω /5 pF
- Sampling Modes Software, onboard programmable pacer, or external
- Input Range (V, software programmable)

Bipolar	-10	+5	+2.5	+1.25	+0.625
Accuracy (% of FSR \pm1LSB)	0.1	0.1	0.2	0.2	0.4

Analog Output (PCI-1711 only)

- Channels 2
- Resolution 12 bits
- Output Rate Static update
- Output Range (V, software programmable)

Internal Reference	Unipolar	0 ~ +5, 0 ~ +10
External Reference		0 ~ +x V @ -x V (-10 \leq x \leq 10)

- Slew Rate 11 V/ μ s
- Driving Capability 3 mA
- Output Impedance 0.81 Ω
- Operation Mode Software polling
- Accuracy INLE: \pm 1 LSB
DNLE: \pm 1 LSB

Digital Inputs

- Channels 16
- Compatibility 5 V/TTL
- Input Voltage Logic 0: 0.8 V max.
Logic 1: 2.0 V min.

Digital Outputs

- Channels 16
- Compatibility 5 V/TTL
- Output Voltage Logic 0: 0.8 V
Logic 1: 2.0 V
- Output Capability Sink: 8.0 mA @ 0.8 V
Source: -0.4 mA @ 2.0 V

Pacer/Counter

- Channels 1
- Resolution 16 bits
- Compatibility 5 V/TTL
- Max. Input Frequency 10 MHz
- Reference Clock Internal: 10 MHz

General

- Bus Type PCI V2.2
- I/O Connector 1 x 68-pin SCSI female connector
- Dimensions (L x H) 175 x 100 mm (6.9" x 3.9")
- Power Consumption

PCI-1711	Typical: +5 V @ 850 mA Max: +5 V @ 1.0 A
PCI-1711L	Typical: +5 V @ 700 mA Max: +5 V @ 1.0 A
- Operating Temperature 0 ~ 60° C (32 ~ 140° F) (refer to IEC 68-2-1, 2)
- Storage Temperature -20 ~ 70° C (-4 ~ 158° F)
- Storage Humidity 5 ~ 95% RH non-condensing (refer to IEC 68-2-3)

Ordering Information

- **PCI-1711** Entry-level 100 kS/s, 12-bit Multifunction Card
- **PCI-1711L** Entry-level 100 kS/s, 12-bit Multi. Card w/o AO
- **PCLD-8710** DIN-rail Wiring Board w/ CJC
- **PCL-10168-1** 68-pin SCSI Shielded Cable, 1 m
- **PCL-10168-2** 68-pin SCSI Shielded Cable, 2 m
- **ADAM-3968** 63-pin DIN-rail SCSI Wiring Board

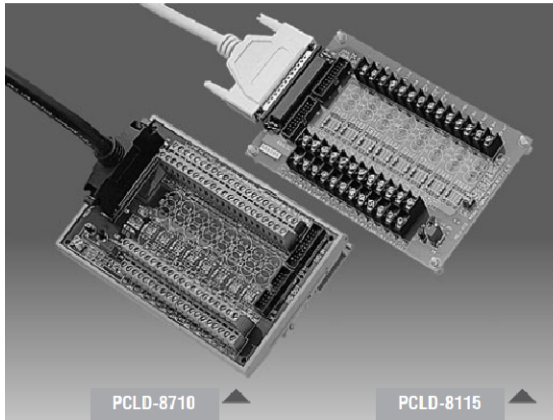
Pin Assignments

AI0	68	34	AI1
AI2	67	33	AI3
AI4	66	32	AI5
AI6	65	31	AI7
AI8	64	30	AI9
AI*0	63	29	AI1*
AI*2	62	28	AI13
AI*4	61	27	AI15
AIGND	60	26	AIGND
AO0_REF	59	25	AO1_REF
AO0_OUT	58	24	AO1_OUT
ADGND	57	23	ADGND
DI0	56	22	DI1
DI2	55	21	DI3
DI4	54	20	DI5
DI6	53	19	DI7
DI8	52	18	DI9
DI*0	51	17	DI11
DI*2	50	16	DI13
DI*4	49	15	DI15
DGND	48	14	DGND
DO0	47	13	DO1
DO2	46	12	DO3
DO4	45	11	DO5
DO6	44	10	DO7
DO8	43	9	DO9
DO*0	42	8	DO11
DO*2	41	7	DO13
DO*4	40	6	DO15
DGND	39	5	DGND
CNT0_CLK	38	4	PACER_OUT
CNT0_OUT	37	3	TRG_GATE
CNT0_GATE	36	2	EXT_TRG
+12V	35	1	+5V

*: Pins 23-25 and pins 57-59 are not defined for PCI-1711L

PCLD-8115 PCLD-8710

Industrial Wiring Terminal Board With CJC Circuit



Features

- Low-cost screw-terminal boards
- Onboard CJC (Cold Junction Compensation) circuits for direct thermocouple measurement.
- Reserved space for signal-conditioning circuits such as low-pass filter, voltage attenuator and current shunt.
- Industrial-grade screw-clamp terminal blocks for heavy-duty and reliable connections.

PCLD-8115 only

- Supports PCL-818 series multifunction cards
- Nylon standoffs, screws and washers included for easy mounting
- Dimensions (W x L): 169 x 112 mm (6.7" x 4.4")

PCLD-8710 only

- Supports PCI-1710/1710L/1710HG/1710HGL/1711/1711L/1716/1716L cards
- DIN-rail mounting case for easy mounting
- Dimensions (W x L x H): 169 x 112 x 51 mm (6.7" x 4.4" x 2.0")

Introduction

The PCLD-8115 screw-terminal board offers convenient and reliable signal wiring for multifunction cards with 20-pin flat cable connectors or DB37 connectors, such as the PCL-818 series cards. PCLD-8710 is designed to match multifunction cards with 68-pin SCSI-II connectors, such as the PCI-1710/1710L/1710HG/1710HGL/1711/1711L/1716/1716L cards. This screw-terminal board also includes cold junction sensing circuitry that allows direct measurements from thermocouple transducers. Together with software compensation and linearization, every thermocouple type can be accommodated.

Due to its special PCB layout, you can install passive components to construct your own signal-conditioning circuits. So you can easily construct a low-pass filter, attenuator or current shunt converter by adding resistors and capacitors onto the board circuit pads.

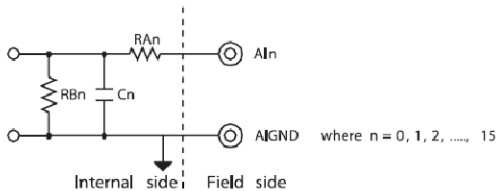
Applications

Field wiring for analog and digital I/O channels of PC-LabCard™ products.

Signal conditioning circuits can be implemented as illustrated in the following examples:

a) Straight-through connection (factory setting)

- $R_{An} = 0 \Omega$ (short)
- $R_{Bn} = \text{none}$
- $C_n = \text{none}$



b) 1.6 kHz (3 dB) low pass filter

- $R_{An} = 10 \text{ K}\Omega$
- $R_{Bn} = \text{none}$
- $C_n = 0.01 \mu\text{F}$

$$f_{3dB} = \frac{R_{Bn}}{R_{An} + R_{Bn}}$$

c) 10 : 1 voltage attenuator:

- $R_{An} = 9 \text{ K}\Omega$
- $R_{Bn} = 1 \text{ K}\Omega$
- $C_n = \text{none}$
- Attenuation = $\frac{R_{Bn}}{R_{An} + R_{Bn}}$
- (Assume source impedance $\ll 10 \text{ K}\Omega$)

d) 4 ~ 20 mA to 1 ~ 5 V_{DC} signal converter:

- $R_{An} = 0 \Omega$ (short)
- $R_{Bn} = 250 \Omega$ (0.1% precision resistor)
- $C_n = \text{none}$

Ordering Information

- **PCLD-8115** Industrial Wiring Terminal Board with CJC circuit and DB37 cable assembly
- **PCLD-8710** Industrial Wiring Terminal Board with CJC circuit for DIN-rail mounting (cable not included)
- **PCL-10137-1** DB37 cable assembly, 1 m
- **PCL-10137-2** DB37 cable assembly, 2 m
- **PCL-10137-3** DB37 cable assembly, 3 m
- **PCL-10168-1** 68-pin SCSI-II cable with special shielding for noise reduction, 1 m
- **PCL-10168-2** 68-pin SCSI-II cable with special shielding for noise reduction, 2 m

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