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NEW DEVICE TO MEASURE LASER BEAM

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ABSTRACT

Introduction:-The energy of a light beam is not spread but is concentrated in certain regions, which propagate like particles. He called these 'particles' *photons*. the observations indicated that light energy is emitted in multiples of a certain minimum energy unit. The size of the unit, which is called a *quantum*, depends on the wavelength λ of the radiation Plank's hypothesis did not require that the energy should be emitted in *localized* bundles and it could, with difficulty, be reconciled with the electromagnetic wave theory. The light is one from of energy. Scientifically speakiy there are three types of formula to express light: the power, energy and the Intensity of light.

The Aim of Project:-

The light is one from of energy. Thus, there must be a formula to express this form of energy. Scientifically speakiy there are three types of formula to express light: the power, energy and the Intensity of light. In this project, we will study how can we express light with reference to the light power by designing the electronic system to achieve this aim. The main aim behind knowing the light power is to determine the usefulness of the light sources and determine the type of sources used (such as the laser which is used for a variety of applications).

Methodology A photodiode differs in that reverse current increases with the light intensity at the pn junction. When there is no incident light, the reverse current I_{λ} is almost negligible and is called the *dark current*. An increase in the amount of light energy produces an increase in the reverse current, In this project, the light will be transferred to electrical signal by using the detection circuit which contains a photo detector. After that we will make the calibration and amplifier for the signal; then we will display the signal on the output device The op. amp. which used in this design is LM392N an the op. amp. & comparator are contained in one package. The device will find applications in transducer amplifiers with pulse shaper D.C gain blocks with level detection, voltage controlled oscillators as well as convention as operational amplifiers or voltage comparator circuits 8-pin d.i.l plastic package equipment to LM392N.

Design Result:

The stander source of light used to design the power meter is He-Ne. laser has power equal to 1 mw. When applying the laser light (1 mw) to photodiode the voltage across between two terminals of photodiode is 450 μv). The photodiode voltage (450 μv) must be amplified to reach of standard value of power (1 mw) by using op. amp. The reference resistance of op. amp. must be large than input resistance of op. amp. by 2.22 time) $R_f = 2.22\ R_{in}$ if take $R_f = 10\ k\Omega$ R_{in} = must be equal 4.5 kΩ /The power meter is operate with 220 V A.C, 12 V D.C When applying 1 mw input of power meter, the output is 0.97 mw. 3- Sensitivity: The maximum sensitivity is meet when wavelength equals 560 nm at this wavelength, the sensitivity is equal to 7 nA / Lux. Complete darkness conditions Temperature: From 20-40^{o}C.Weight: 1550gm. Price: 50 $.

INTRODUCTION:

1) INTRODUCTION

During the 17th Century two emissions theories on the nature of light were developed, the wave theory of Hooke and Huygens and the corpuscular theory of Network. Subsequence observations by Young, Malus, Euler and others lent support to the wave theory. Then in 1864 Maxwell combined the equations of electromagnetism in a general form and showed that they suggest the existence of transverse electromagnetic waves. The speed of propagation in free space of light waves was given by:

$$C = \sqrt{\frac{1}{\mu_0 \varepsilon_0}}$$

Type of radiation	Wavelength	Frequency (Hz)	Quantum energy (eV)
	100 km	3×10^{3}	1.2×10^{-11}
Radio waves			
	300 mm	10^{9}	4×10^{-6}
Microwaves			
	0.3 mm	10^{12}	4×10^{-3}
Infrared			
	0.7 μm	4.3×10^{14}	1.8
Visible			
	0.4 μm	7.5×10^{14}	3.1
Ultraviolet			
	0.03 μm	10^{16}	40
X ray			
	0.1 nm	3×10^{18}	1.2×10^{4}
γ ray			
	1 pm	3×10^{20}	1.2×10^{6}

Table 1 The electromagnetic spectrum

where μ_0 ε_0 are the permeability and permittivity of free space respectively. Substitution of the experimentally determined values of μ_0 and ε_0 yielded a value for c in very close agreement with the value of the speed of light in vacuo measured independently. Maxwell therefore proposed that light was an electromagnetic wave having a speed c of 3×10^{8} ms^{-1}, a frequency of some 5×10^{14} Hz and a wavelength of about 500 nm. Maxwell's theory suggested the possibility of producing electromagnetic waves with a wide range of frequencies (or wavelengths). In 1887 Hertz succeeded in generating non-visible electromagnetic waves, with a wavelength of the order of 10 m, by discharging an induction coil across a spark gap thereby setting up oscillating electric and magnetic fields. Visible light and Hertzian waves are part of the electromagnetic spectrum which, as we can see from Table1, extends approximately over the wavelength range of 1.0 pm to 100 km. The wave theory thus became the accept theory of light. However, while the wave theory, as we shall see below, provides an explanation of optical phenomena such as interference and diffraction, it fails completely when applied to situations where energy is exchanged, such as in the emission and absorption of light and the photoelectric effect. The photoelectric effect, which is the emission of electrons from the surfaces of solids when irradiated, was explained by Einstein in 1905. He suggested that the energy of a light beam is not spread but is concentrated in certain regions, which propagate like particles. He called these 'particles' photons.

Einstein was lead to the concept of photons by the work of Planck on the emission of light from hot bodies. Planck found that the observations indicated that light energy is emitted in multiples of a certain minimum energy unit. The size of the unit, which is called a quantum, depends on the wavelength λ of the radiation and is given by

$$E = \frac{hc}{\lambda}$$

where h is Planck's constant. Plank's hypothesis did not require that the energy should be emitted in localized bundles and it could, with difficulty, be reconciled with the electromagnetic wave theory. When Einstein showed however, that it seemed necessary to assume the concentration of energy traveling through space as particles, a wave solution was excluded. Thus we have a particle theory also; light apparently has a dual nature!

The two theories of light are not in conflict but rather they are complementary. For our purposes it is sufficient to accept that in many experiments, expecially those involving the exchange of energy, the particle (photon or quantum) nature of light dominates the wave nature. On the other hand, for experiments involving interference or diffraction, where light interacts with light, the wave nature dominates.

2) The Aim of Project

The light is one from of energy. Thus, there must be a formula to express this form of energy. Scientifically speakiy there are three types of formula to express light: the power, energy and the Intensity of light.

In this project, we will study how can we express light with reference to the light power by designing the electronic system to achieve this aim.

The main aim behind knowing the light power is to determine the usefulness of the light sources and determine the type of sources used (such as the laser which is used for a variety of applications). In the medical field, we must know the power and wavelength of laser light to manage using the laser correctly in the treatment of the organs or diagnostic applications.

The table shows below the typical laser characteristic along with its medical applications.

Laser	**Wave length (μm)**	**Solid or gas**	**Typical power (watt)**		**Type of beam**	**Applied field**
			Continuos wave	**Peak**		
Argon	0.49 0.52 visible	Gas	5	100	Continuous tunable pulsed	Neurosurgery, opthalmology, general surgery, gynaecology, dermatology, biological research
Helium, Neon	0.63 1.15 3.39 visible	Gas	0.1	2	Continuous	Diagnostic applications like study of light, permeability of blood containing tissues, laser holography, etc.
Krypton	0.35 UV	gas	5	100	Continuous	Opthalmology and for general Diagnostic use
Ruby	0.69 visible	Solid	5	50	Pulsed	Opthalmology, dermatology
Co_2	10.6 IR	Gas	200	75.000	Continuous pulsed	Neurosurgery, general surgery, dermatology, gynaecology
Nd-YAG	1.06 IR	Solid	50	1.000	Q-switched continuous	Neurosurgery, dermatology, gynaecology

3) The Theoretical Side

Photodiode

The photodiode is a pn junction device that operates in reverse bias, as shown in Figure (1-a). Note the schematic symbol for the photodiode. The photodiode has a small transparent window that allows light to strike the pn junction. Typical photodiodes are shown in part (b).

Recall that a rectifier diode has a very small reverse leakage current when reverse-biased. The same is true for the photodiode. The reverse-biased current is produced by thermally generated electron-hole pairs in the depletion layer, which are swept across the junction by the electric field created by the reverse voltage. In a rectifier diode, the reverse leakage current increases with temperature due to an increase in the number of electron-hole pairs.

A photodiode differs in that reverse current increases with the light intensity at the pn junction. When there is no incident light, the reverse current I_λ is almost negligible and is called the dark current. An increase in the amount of light energy produces an increase in the reverse current, as shown by the graph in Figure (2-a). For a given value of reverse-bias voltage, part (b) shows a set of characteristic curves for a typical photodiode.

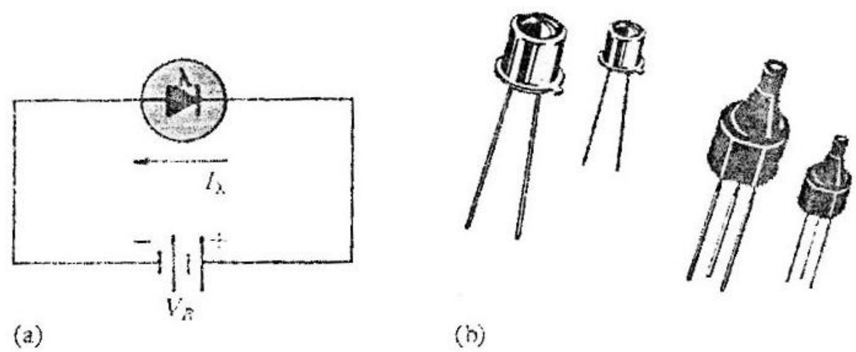


Figure (1) Photodiode

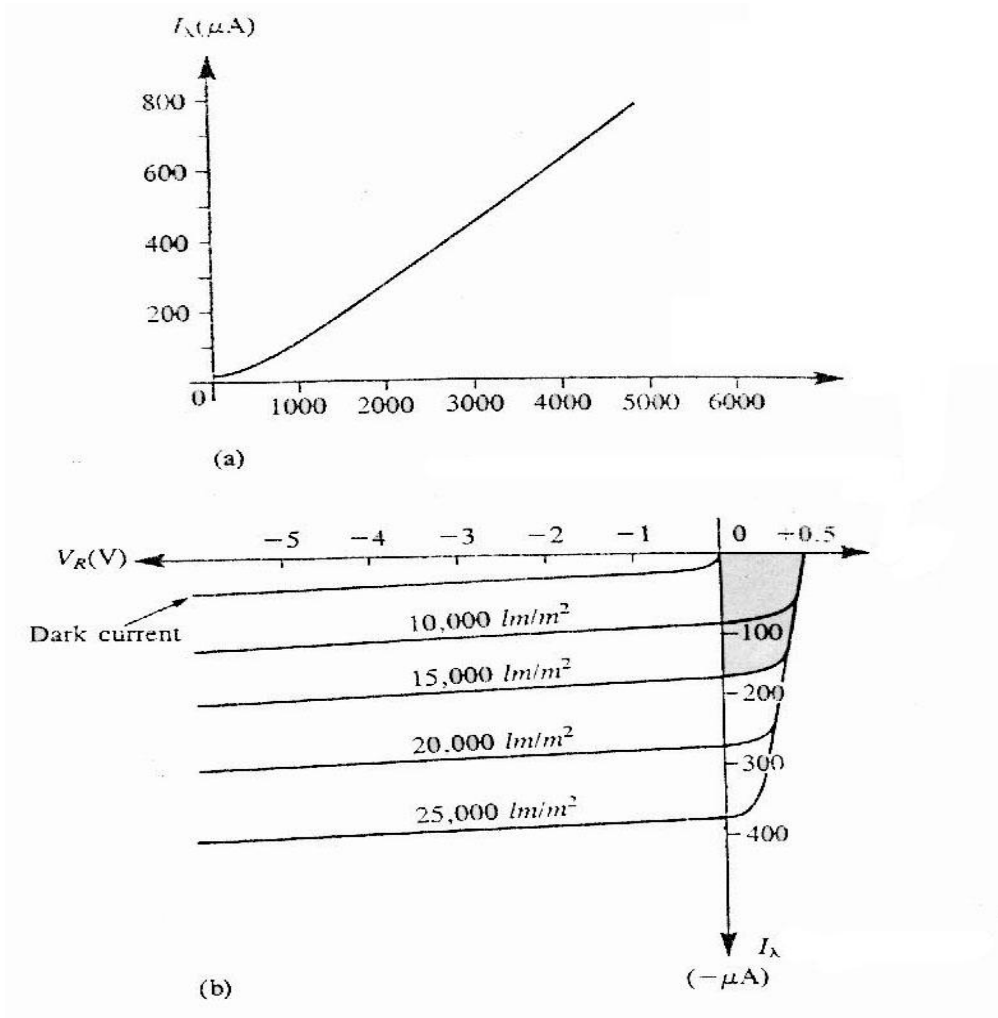


Figure (2) Typical Photodiode Characteristics

From the characteristic curve in Figure (2-b), the dark current for this particular device is approximately 25 μA at a reverse bias voltage of 3 V. Therefore, the resistance of the device with no incident light is

$$r_R = \frac{V_R}{I_\lambda} = \frac{3V}{25\,\mu A} = 120\,k\Omega$$

At 25.000 lm/m², the current is approximately 375 μA at –3 V. The resistance under this condition is

$$r_R = \frac{V_R}{I_\lambda} = \frac{3V}{375\,\mu A} = 8\,k\Omega$$

These calculations show that the photodiode can be used as a variable resistance device controlled by light intensity. The photodiode differs, of course, from the photo-conductive cell in that it conducts current in only on direction.

Note:-

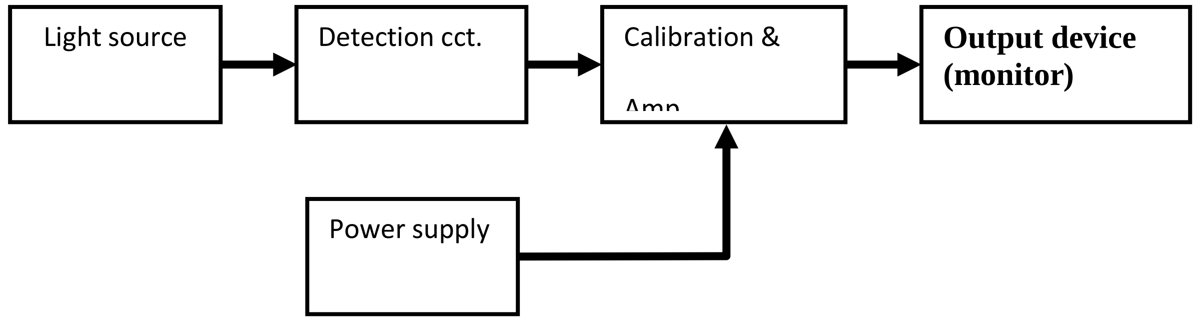
And there are many detectors for example, avalanche diode.

4) The Practical Side:

When designing the instrument to measure the light power, we must have a system that can transfer the light to a signal that can be dealt with (such as electrical signal).

In this project, the light will be transferred to electrical signal by using the detection circuit which contains a photo detector. After that we will make the calibration and amplifier for the signal; then we will display the signal on the output device.

The Figure below illustrates the block diagram for power meter.



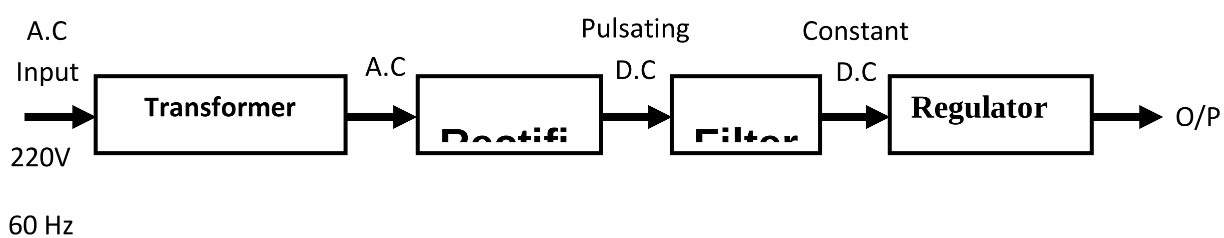
1- Light Sources:

The instrument was designed to measure the light power in the visible region, (i.e. the light has wavelength ranging from 400 nm to 700 nm).

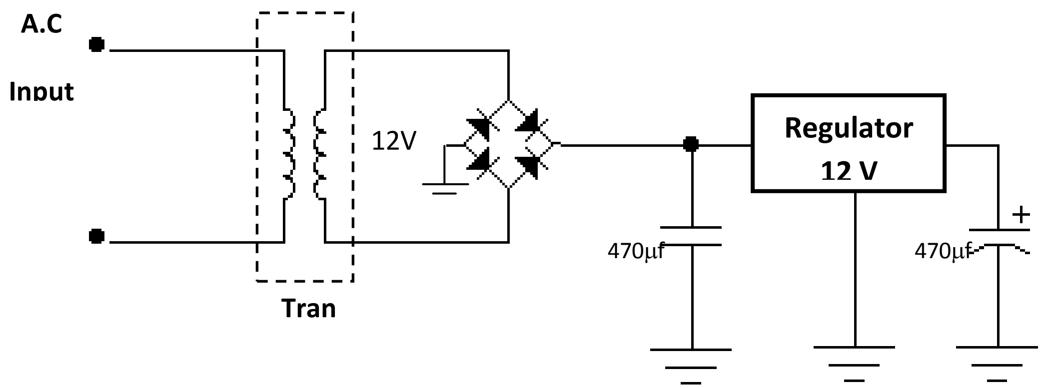
2- Power Supply:

All system requires power to operate. Any system requires a power supply to provide. D.C voltage & current , the power supply can be considered an integrate part of system power supply.

Below Figure shown a block diagram of typical D.C power supply.



The electrical cct. of power supply is shown in Figure below.



The input usually 220/110 V, 60 Hz A.C a transformer couples this A.C voltage to rectifier with current A.C to pulsating D.C.

The filter smooth out the pulsating D.C & produces a relatively constant D.C voltage level.

The regulator serves to keep the D.C voltage constant over range of input or lead fluctuation.

(Some systems may operate without regulator).

3- Detection cct.:

Used in this circuit detector from type p-n (as we explained) to convert photo-signal to electrical signal. In addition to variable resistance to controlled the sensitivity of photodiode.

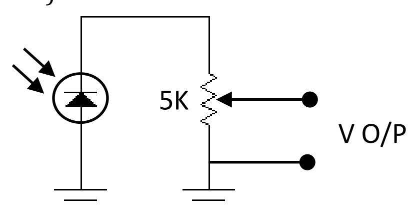
5) Photo Diode (BPW21)

A silicon photodiode housed in an hermetically sealed can with a flat window in carporating built in color correction filter (visible radiation) may be used in the photo voltaic mode, suitable for use in light monitoring and control camera exposure control, verifying lighting safety standard.

6) Technical Specification:

Peak spectral response	560 nm
Wave length range	460 – 750 nm
Sensitivity (short circuit)	7 nA / Lux
Open cct. volts (E=1 k Lux)	280 mv
Dark current (V_R=5V)	2 nA
Rise time (I=100 nA , Rl= 1 kΩ)	3.5 µs
Junction capacitance (V_R=5V)	170 pf

The resistance is a variable one which is equal (5 kΩ)

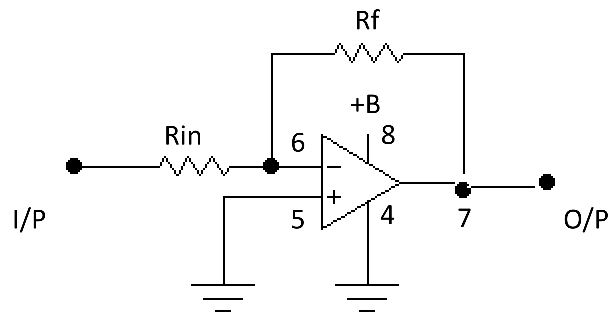


4- Calibration & Amplifier cct.:

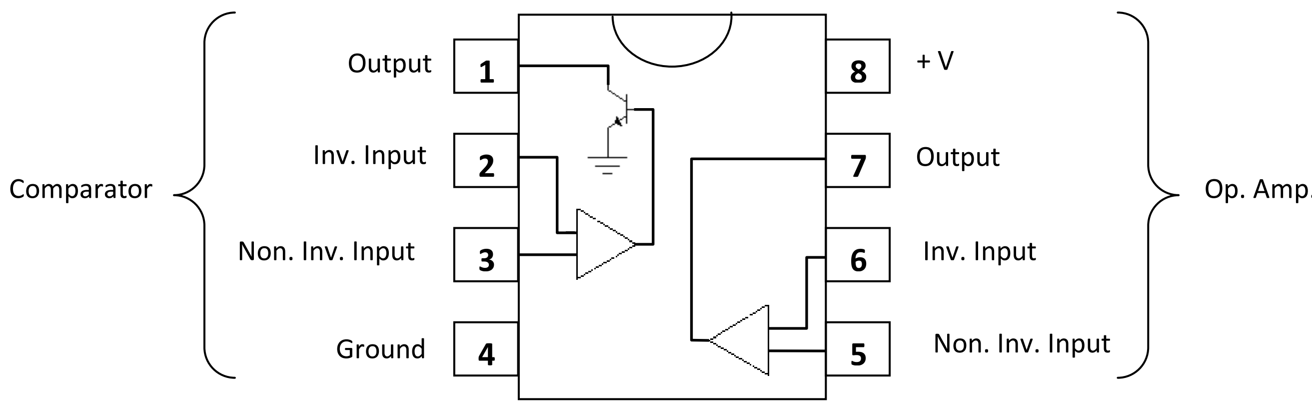
The power meter must be calibrated, with standard light source (in the power of it is know). We used in this design He-Ne laser has 1 mw stable power.

The output of photodiode can be calibrated with the standard source by using op. amp. which increased or decreased under the effect of the value of resistance (Rf & Rin) for op. amp. to obtain stander value.

The electrical cct. for calibration & amp. cct. is shown in Figure below.



The op. amp. which used in this design is LM392N an the op. amp. & comparator are contained in one package.



The 392 consist of an independent high gain internally compensated operational amplifier and a precision open collector voltage comparator. Both the operational amplifier and voltage comparator will operate from a single or dual supply. The device will find applications in transducer amplifiers with pulse shaper D.C gain blocks with level detection, voltage controlled oscillators as well as convention as operational amplifiers or voltage comparator circuits 8-pin d.i.l plastic package equipment to LM392N.

5- The output device:

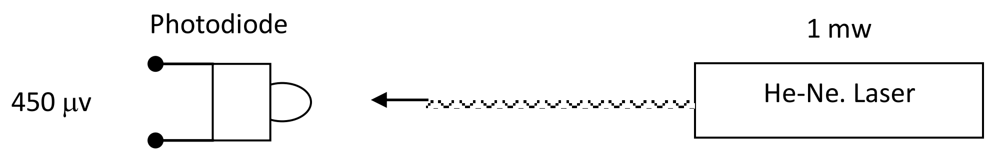
After amplifying & processing the signal, it must be displayed on the output device. In this project, the output device is digital multimeter which contains:

1- Display monitor to display the value of power light.
2- Function and range switch. This switch is used as ON/OFF switch to the display monitor and is also used to select the suitable range.
3- Two terminals for connection: the first terminal is connected with the output of op. amp. and the second terminal is connected to ground.

7) Design Result:

The stander source of light used to design the power meter is He-Ne. laser has power equal to 1 mw.

When applying the laser light (1 mw) to photodiode the voltage across between two terminals of photodiode is 450 μv).



The photodiode voltage (450 μv) must be amplified to reach of standard value of power (1 mw) by using op. amp. which has overall gain equal ($Av = \frac{1mw}{450\,\mu} = 2.22$). (i.e the Av=2.22 , $\frac{R_f}{R_{in}} = 2.22$).

The reference resistance of op. amp. must be large than input resistance of op. amp. by 2.22 time)

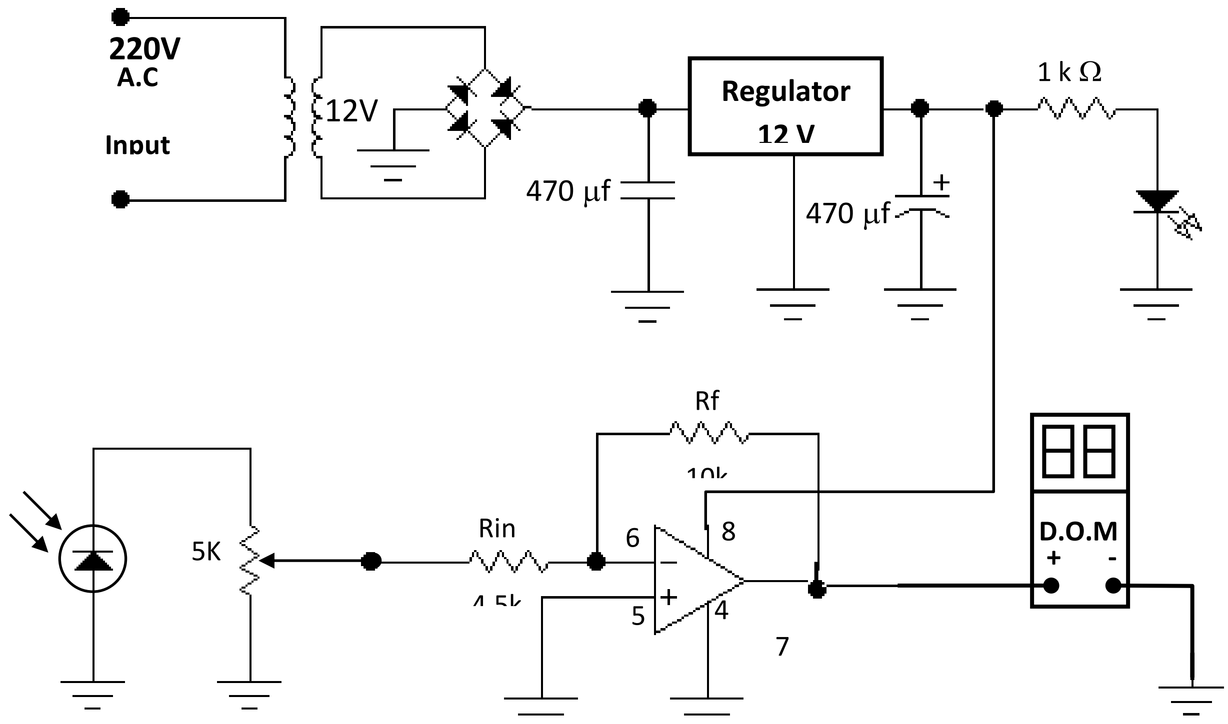
$R_f = 2.22\ R_{in}$

if take $R_f = 10\ k\Omega$ R_{in} = must be equal 4.5 kΩ

Note:

The properties of He-Ne. laser are λ = 632.8 nm , P=1 mw.

8) The Complete Circuit



9) The Total Properties of Power Meter

1- Operation voltage: The power meter is operate with 220 V A.C, 12 V D.C

2- Efficiency: When applying 1 mw input of power meter, the output is 0.97 mw.

The efficiency of power meter = $\frac{0.97\,mw}{1mw} \times 10\%$, $\eta = 97\%$.

3- Sensitivity: The maximum sensitivity is meet when wavelength equals 560 nm at this wavelength, the sensitivity is equal to 7 nA / Lux.

4- Operation condition: Complete darkness conditions.

5- Temperature: From 20-40^{o}C.

6- Weight: 1550gm.

Reference

1- Optoelectronics An Introduction, J. Welson, J. F. B. Hawkes,1983.
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