Centre of Excellence (CoE), a MeitY and U.P. Government sponsored project implemented by CDAC Noida and India Cellular & Electronics Association (ICEA)

Grand Challenge Contest 2021

Design Report

General Information:

Team Name	Minute Wave
Registered Mail ID	blessoabraham@gmail.com
Problem Statement Code	P-003
Problem Statement	To design a low-cost Wireless Charger

Team Details:

	Team Lead	Team Member 1	Team Member 2
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Checklist of files to be attached with the e-mail:

1) Attached Schematic file (PDF Format): Yes
2) Attached Layout file (PDF Format): Yes
3) Attached BOM list (PDF Format): Yes
4) Attached Gerber file (PDF Format): Yes
5) Attached Centroid file (Pick and Place): No
6) Attached IPR undertaking form (PDF File): Yes

a) Hardware Tools Used:
Semiconductor Pump Laser Diode, Gain Medium, Wave Guide, Photovoltaic Cell, Retro-reflector, Auxiliary Mirror, Focusing Mirror.

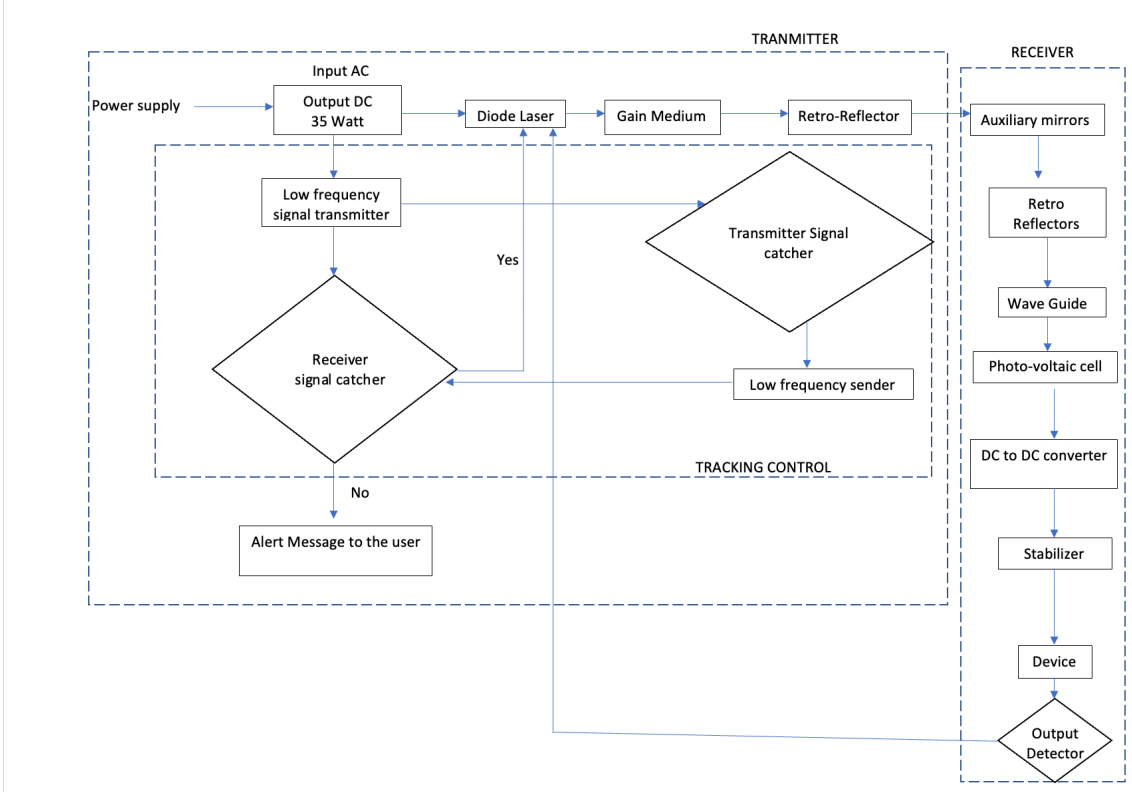
b) Software Tools Used:
Autodesk AutoCAD, Autodesk EAGLE, Multisim, TinkerCAD.

c) Technical Specifications of the Product:

Transmitter Specifications	Values
Delivered Power	5 Watts
Supports Multiple Receivers	Yes
Range	10 meters
Input Voltage	12 volts
Temperature Range	5°-55°C
Technology	IR based Power Transfer

Receiver Specifications	Values
Maximum Output Power	5V @ 2A
Connector	Type C
Interface	5V ± 0.25V
Operating Temperature Range	5°-45°

1) Detailed Block Diagram of the Product Design:



2) New/Extra features incorporated in the product design:

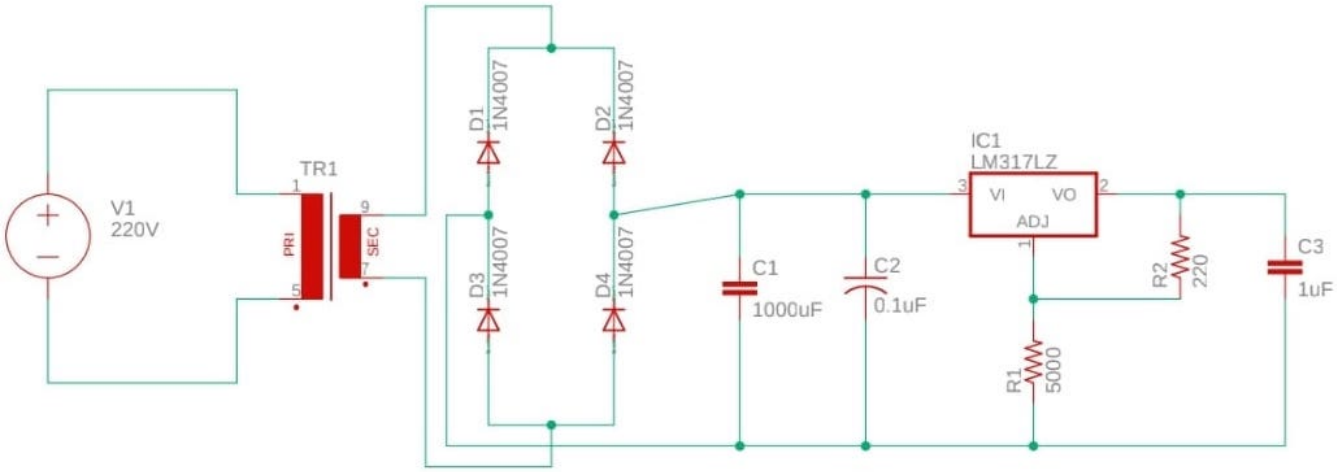
- The losses occur in the Magnetic Inductive Charger completely avoided in this product.
- The power loss of the product is very less when considered to Inductive Wireless Charger due to distance.
- No direct contact or placement of any surfaces is needed
- True Wireless Power can be experienced.

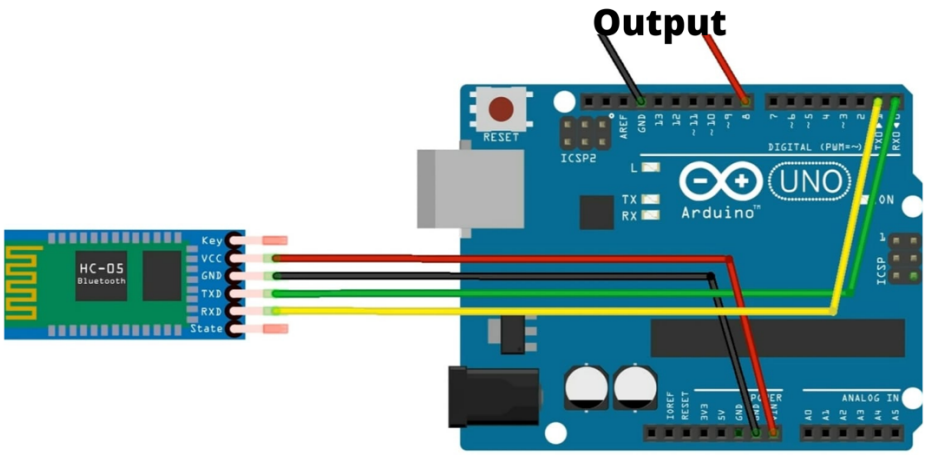
3) Detailed Explanation of Circuitry:

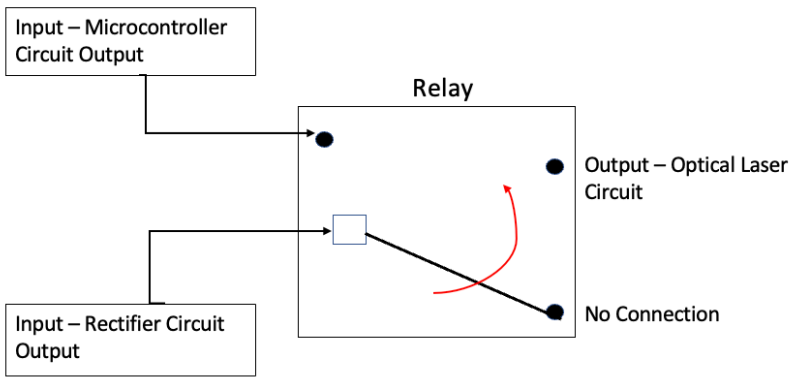
The transmitter consisting of a proposed retro-reflector and a gain medium from a Semiconductor Diode. A pump laser diode feeds power to the gain medium to stimulate 1064-nm infrared resonant beam. The receiver consists of a proposed retro-reflector with 90% reflectivity, a focal lens, a waveguide, and a photovoltaic panel. Passing through the focal lens and the waveguide, the output beam from the retro-reflector is incident on the photovoltaic panel. The radii of lenses and mirrors in the retro-reflectors at both the transmitter and the receiver are 7 mm.

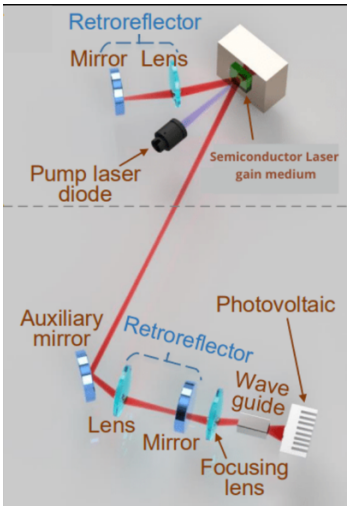
The photovoltaic panel size is 10×6 mm^2. A direct current to direct current (DC-DC) converter with 5 V output voltage is used to connect the photovoltaic panel with an electronic device. A 12 × 12 mm semiconductor diode gain medium is adopted at the transmitter. A steel disc with a hole radius of 2.8 mm is attached to the surface of the gain medium to fix the medium onto the cooling module. All mirrors and lenses in the retro-reflectors are attached to an aperture with radius of 7 mm. At the receiver, the wave guide is coated with silver so that most light energy can be guided to the photovoltaic panel. The retro-reflectors at the transmitter and receiver share the same configuration. The focal length of the lens in the retro-reflector is 50 mm (±1%). The interval between the lens principal plane and the mirror is 52 mm (the principal plane of the lens is closer to the mirror, and the distance from which to the centre of the lens is calculated to be 0.9 mm). The input power to gain medium is 37.3 W. The reflectivity of the mirror in the retro-reflector at the transmitter is near 1. However, the reflectivity of the mirror at the receiver is 0.9, which means 0.1 beam power can pass through the mirror. Particularly, the double-retro-reflector cavity enables automatically charging a compact size moving receiver without tracking control. Measurement data from an infrared-frequency prototype support the theoretical analysis. Thus, the mechanism of self-aligned resonant beam enables simultaneously long-distance and high efficiency in mobile energy transfer without tracking control. This type of technology will make to charge a device whenever and wherever required which does not depend on the size of the device's battery. This will allow the mobile phone producer to make a small sized battery which will give more space to work with the other components.

4) Screenshot of Schematic of the product design:

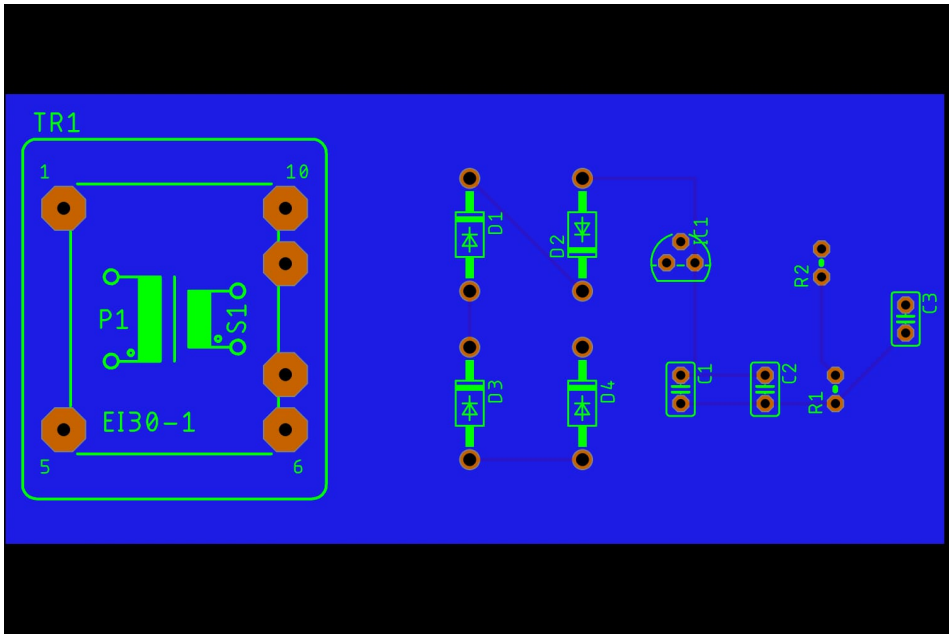


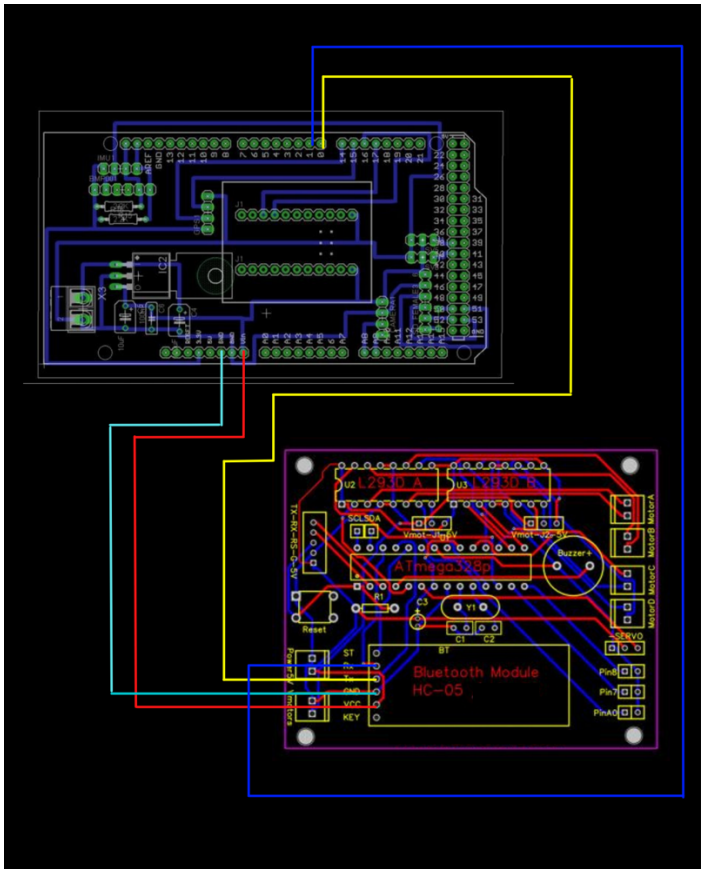




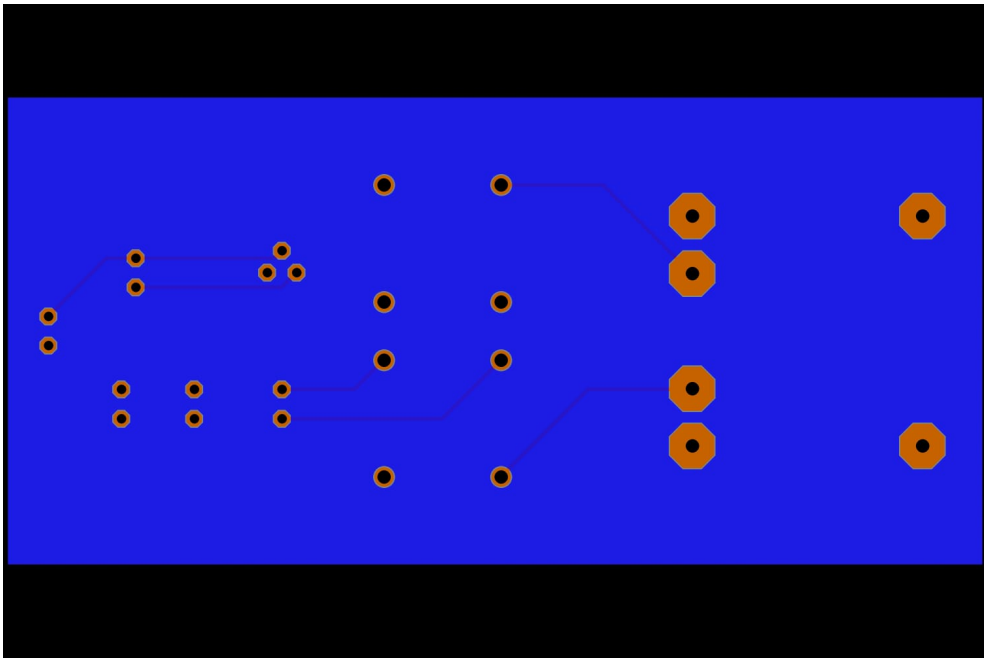


5) PCB Layout TOP Layer:

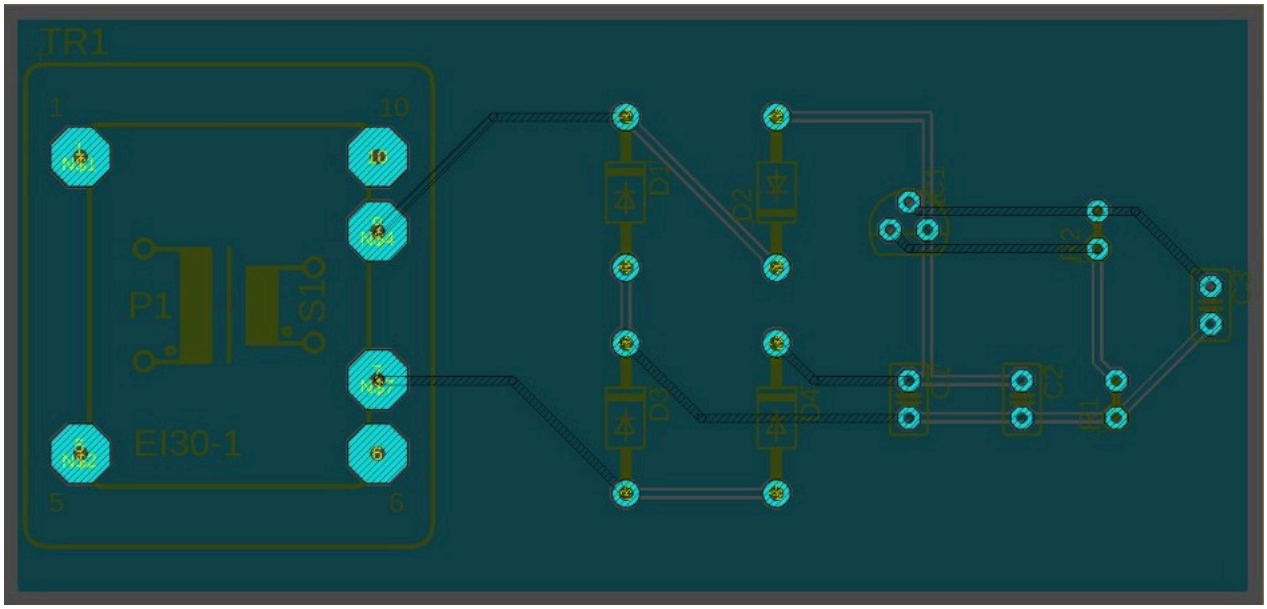




6) **PCB Layout Bottom Layer:**



7) **PCB Ground Layer:**



8) **Gerber File Description:**
This Gerber file contains the PCB Layout of the Rectifier circuit. The batch and bias layer contains drills of the PCB design. The tplace layer contains the components of the PCB design. The tnames layer has the names of the components present in the tplace layer. The top and bottom contains the connecting wires of the components in the tplace layer.

9) **Board Dimensions:** Width 84.76 (mm) x Height 40.65 (mm)

10) **Number of layers of the PCB:** 14

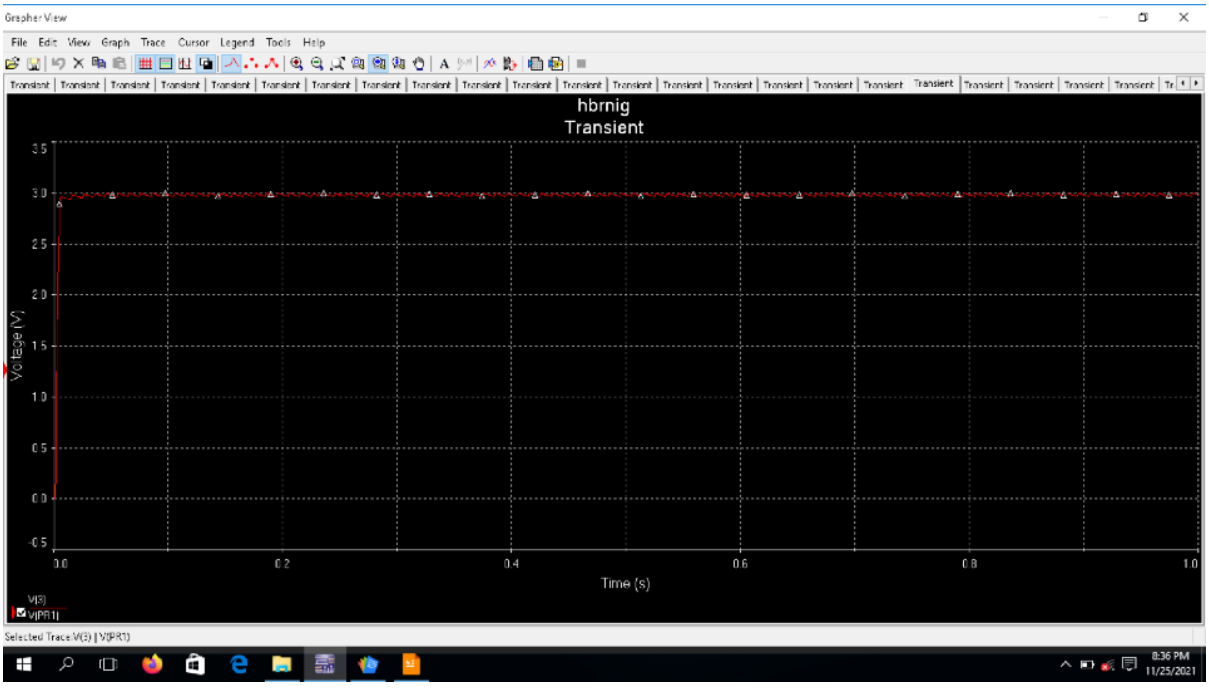
11) **Elaborate on techniques used to mitigate Electro Magnetic Interference (EMI) in your product design.**
There is negligible amount of Electro Magnetic Interference in our product. So, there is no need to mitigate it.

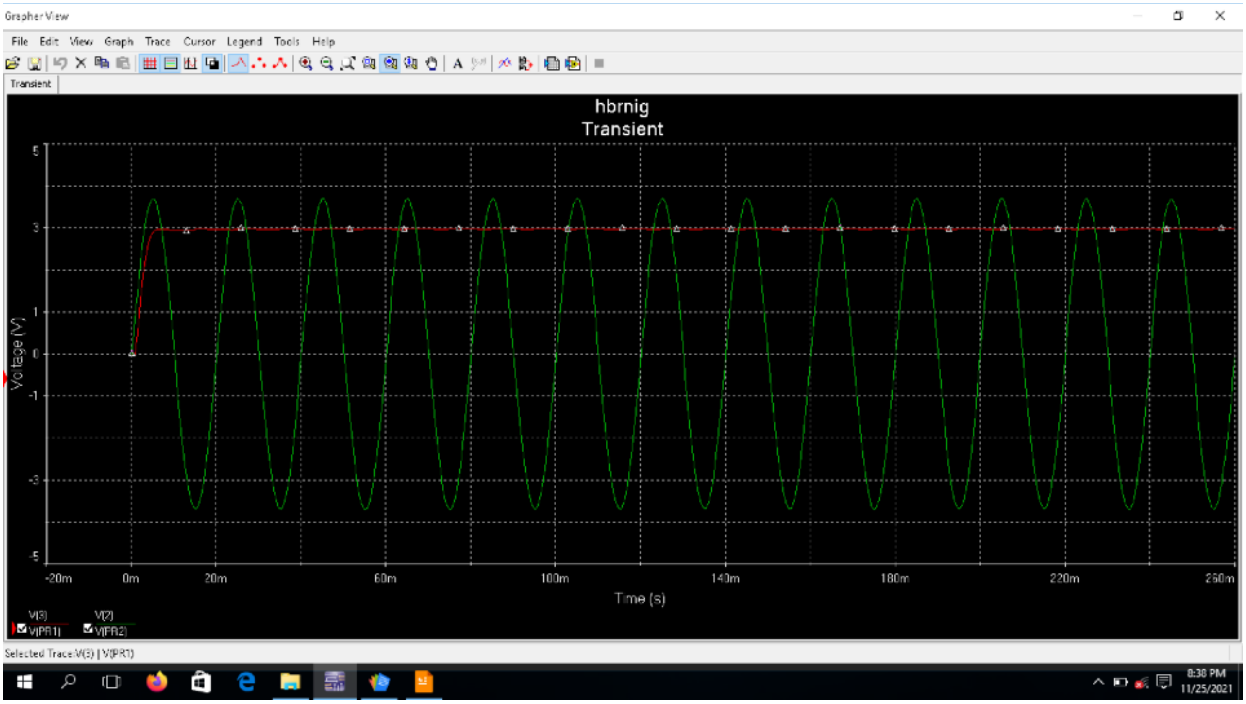
12) **What are the factors considered to improve the Efficiency in your product design?**
- There is no loss in the atmosphere medium while the power is transferred to the receiver. Because of the higher wavelength of the IR Resonant Beam.
- Using Range Detecting Circuit, we can able to detect and control the IR Resonant Beam.

13) **Elaborate on techniques used to mitigate Total Harmonic Distortion (THD) in your product design.**
There is no harmonic distortion takes place in the product.

14) **Elaborate the factors considered to improve power factor in your product design.**
- By using an efficient way to rectify the AC input.
- Using optical circuit, we can improve the power factor.

15) **Detailed explanation of the test results/simulation results along with the screenshot .**





The voltage source is given to a step-down transformer rated at (0-12V, 5A). Then, the secondary terminal of the transformer is connected to a bridge network of PN junction diodes. The bridge network consists of 4 PN junction diode (IN4007). In which, the diode are connected in a way that D1 and D4 conducts electricity during the positive cycle also converts the AC input signal to DC output. During, the negative cycle D2 and D3 conducts electricity. So, the AC input signal is converted into DC completely. Then, a 1000μF capacitor is connected across the network. This capacitor works as a filter to reduce the ripple factor of the DC Output signal. A coupling capacitor of 0.1 μF is connected across the 1000 μF capacitor, in order to block the AC signal from the circuit. Then, a voltage regulator is connected. The input signal of the regulator is given by output signal of the coupling capacitor. The voltage regulator is used to maintain the voltage of the output signal of the coupling capacitor within the limit of 3V. So, that the output voltage remains the same, even the input voltage source fluctuates. The output terminal of the regulator is used to take the power. The adjacent terminal of the regulator is connected with another resistive filter. The output DC voltage and input AC voltage signal is shown in the simulation. And, the output voltage vs time graph is shown in the simulation.

16) Bill of Material (BoM) Sample:

S.No	Name of the Component	Description	Manufacturer Part Number	Manufacturer	Quantity	Unit Cost	Total Cost
1.	TR1	0-12V, 5A	EC-3449	Generic	1	647.82	647.82
2.	D1,D2, D3,D4	IN4007	EC-0144	Generic	5	1.18	5.90
3.	C1	1000μF, 16V	EC-0786	Generic	1	22.42	22.42

4.	C2	0.1μF	EC-0018	Generic	1	3.54	3.54
5.	C3	1μF	EC-1210	Generic	1	9.44	9.44
6.	R1	5000Ω	RSF/MO5WS5KJBU	Jameco Valuepro	1	11.20	11.20
7.	R2	220	EC-1060	Generic	1	7.80	7.80
8.	IC1	LM317LZ	EC-0206	Generic	1	16.52	16.52
9.	Arduino UNO	R3 ATMEGA328P EVAL	1050-1024-ND	Arduino	1	1000.00	1000.00
10.	HC-05	9600bps	TECH1537	Techtonics	1	365.00	365.00
11.	Relay	1 Channel 12V	EC-6574	Generic	1	135.70	135.70
12.	Pump Laser Diode	980nm Laser Diode	HTRM-48	Zhongshan He Tong Optics	1	300.21	300.21
13.	Gain Medium	ND YAG Laser Crystal	8456110090	Wuhan TA Laser Machinery	1	1050.74	1050.74
14.	Retroreflectors	5x5x5 cm	FZ79014506	Felzon	1	1361.01	1361.01
15.	Auxiliary Mirror	19.05mm Diameter	15D935AE3J7Y1J	Jing'ao	1	1801.27	1801.27
16.	Wave Guide	2x2x1 cm	EC-0952	Generic	1	2000.00	2000.00
17.	Photo-Voltaic Cell	70x70mm	ELEC100MA-12V	Hello Creators	1	77.00	77.00
18.	Output Coupler	Nd:YAG output coupler	HTRM-48	Zhongshan He Tong Optics	1	6000.00	6000.00

17) Any other relevant information/analysis:

a) Principal of proposed Retro-reflector:

According to geometric optics, a ray passes through an optical component can be described as the ray vector multiplied by a matrix, i.e., the ray-transfer matrix under the paraxial approximation, as

$$\begin{bmatrix} x_i \\ \theta_i \end{bmatrix} = \mathbf{M_0} \begin{bmatrix} x_o \\ \theta_o \end{bmatrix}, \qquad (1)$$

here x_i and x_o are the transverse displacements of the input ray and output ray from the optical axis, respectively, while θ_i and θ_o are the slopes of the input ray and output ray, respectively. Moreover, if the ray passes through a series of optical components, the overall ray-transfer matrix is the production of individual matrices of these components with the opposite order. Thus, for the proposed retroreflector, the ray-transfer matrix describes a ray passes through the free space from the focal plane of the lens to the lens, the lens, the free space from the lens to the mirror, the mirror, the free space from the lens to the mirror, the lens, and the free space from the lens to the focal plane of the lens in sequence, which is depicted as [21, 22].

$$\mathbf{M} = \begin{bmatrix} 1 & f \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix} \begin{bmatrix} 1 & l \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & l \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix} \begin{bmatrix} 1 & f \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1/f_{\mathrm{RR}} & 1 \end{bmatrix} \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}, \quad (2)$$

where

$$f_{\mathrm{RR}} = 1 \Big/ \left(\frac{2l}{f^2} - \frac{2}{f} \right). \quad (3)$$

f is the focal length of the lens and l is the interval between the flat mirror and lens in the retro-reflector. If $l=f$ for the cat's eye retroreflector, the equation (2) will become

$$\mathbf{M_c} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}. \quad (4)$$

Thus, $xo = -xi$ and $\theta o = -\theta i$, i.e., the input ray passes through the reflector will return in the reverse direction. If $l > f$ for the proposed retro-reflector, the equation (2) will become

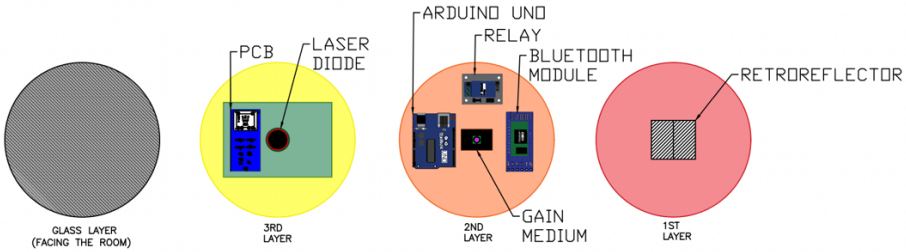
$$\mathbf{M_r} = \begin{bmatrix} -1 & 0 \\ 1/f_{\mathrm{RR}} & -1 \end{bmatrix}. \quad (5)$$

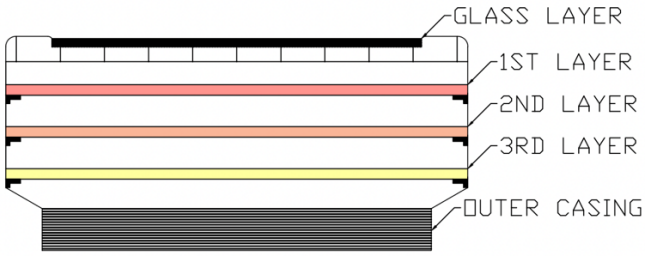
Thus, $xo = -xi$ and $\theta o = -\theta i + 1/f\mathrm{RR}$, i.e., the retro reflector exhibits the capability of beam focusing. The transmitter includes a proposed retro-reflector and a gain medium. The receiver includes the other proposed retro-reflector. The collaboration between these two retro-reflectors leads to the self-alignment feature of the cavity, where the resonant beam can be established between these two retro-reflectors, even when the relative position of the transmitter and the receiver changes. Based on laser principle, the gain medium acts as a power amplifier, which is fed by the input power and stimulates a resonant beam. If the retro-reflector at the receiver is partially reflective, the resonant beam can partly pass through to form an output beam, i.e., laser. Then, the output beam can be converted to electricity by a photovoltaic panel.

b) Transmitter and Receiver Design Layout:

- The transmitter first layer contains retro-reflectors.
- The transmitter second layer contains Arduino Uno, HC-05 (Bluetooth Module), Relay and Gain Medium.
- The transmitter third layer contains PCB and Pump laser diode.
- The transmitter outer layer is covered by a glass cover.
- The receiver has three layers which has Retro-reflectors, Gain Medium and Photo-Voltaic Cell in the respective order.
- The receiver end has charger pin which is connected through wires (inside the case) to the receiver panel.

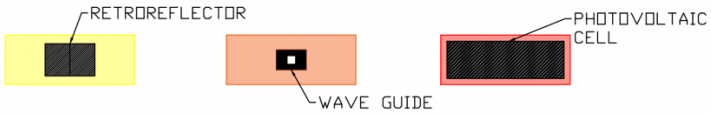
TRANSMITTER LAYOUT

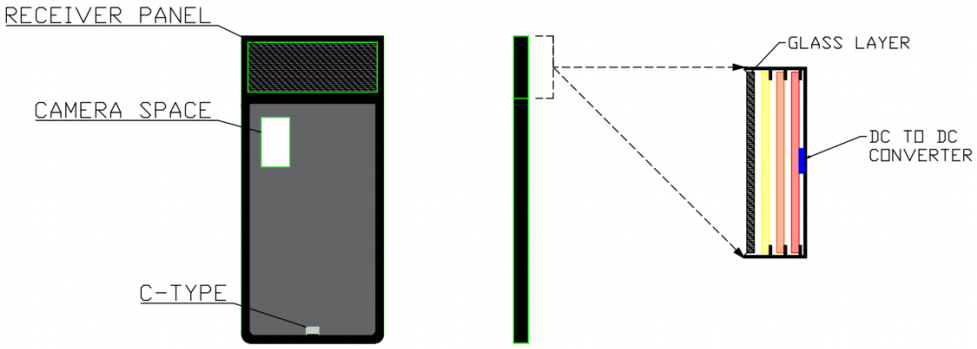




PRODUCT LAYOUT

RECEIVER LAYOUT





TOP VIEW SIDE VIEW