Wireless Charging Pacemaker

Introduction:

As technology makes rapid strides in all spheres of everyday life, there arises the enduring demand for health-care and monitoring devices that are not only accurate, but also efficient. Many of the bio-sensors and bio-devices today are implantable, which means that they are embedded inside the body of the subject. Understandably, then, arises the question of powering such devices.

The answer to which is :**Wireless Charging.**

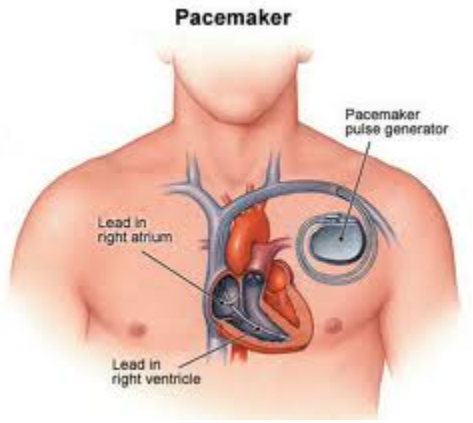
Millions of people around the world benefit from having artificial pacemakers implanted into their chests, to help restore a normal heartbeat. Yet pacemakers are not without problems. The bulk of the device—which contains its battery and electronic control systems—usually sits just under the wearer's skin. From this box thin, flexible leads are threaded through a vein and into the appropriate part of the heart. These leads detect the heart's electrical activity (which controls when it contracts, and is regulated by a cluster of specialized muscle cells that act as a natural pacemaker), transmit that information to the artificial pacemaker's electronics for analysis and, if the natural activity is deemed irregular, deliver an electrical charge from the artificial pacemaker's batteries that causes the cardiac muscle to contract, pacing the pumping of the heart. Currently, many of these devices run on big, long-lasting batteries that still eventually die, generally requiring another round of surgery.

Thus to eliminate the bulky batteries and clumsy recharging systems that prevent medical devices from being more widely used, we devised a pacemaker with wireless charging capabilities in order to reduce surgical risk to patients and associated healthcare costs. Earlier, the pacemaker needed to be replaced surgically when the battery run out. With this project, the painstaking and risky process is no longer required!

To provide a deeper insight to our proposed model we would like to express the overall architecture of the project right from: what the model is all about, going through its working to the final 3D proposed model of the concerned product that we aim to build up along with a DIY explanation of the core component of the product, that is the pulse generating circuit.

Overview:

Cardiac pacemakers are used to treat a heart that beats too slowly. Sometimes the natural pacemaker of the heart becomes diseased and does not keep the heart beating regularly. The average heart rate is 60 to 100 beats per minute. The normal heart can occasionally beat as slowly as 40 times a minute while resting and as fast as 200 times a minute while exercising. However there can be symptoms of weakness, dizziness and fainting when the heart beats to slowly. The heart may always be slow or there may be episodic pauses in the heartbeat that may lead to symptoms.



What is Cardiac Pacemaker?

Cardiac Pacemaker is a small device that's placed in the chest or abdomen to help control abnormal heart rhythms. This device uses electrical pulses to prompt the heart to beat at a normal rate. Pacemakers are used to treat arrhythmias. Arrhythmias are problems with the rate or rhythm of the heartbeat. During an arrhythmia, the heart can beat too fast, too slow, or with an irregular rhythm.

Why Cardiac Pacemakers?

Cardiac pacemakers are required in order to help the heart to beat regularly and send the blood which is rich in oxygen and nutrients to the rest of the body. Cardiac pacemakers are used for a number of reasons. These include:

1. A very slow heart rate leading to symptoms of fatigue, weakness and dizziness
2. A diagnosis found with an electrocardiogram that indicates a potential for sudden drastic
3. Drops in the heart rate
4. Injury to the heart muscle that may occur after a heart attack that interferes with your
5. Heart’s ability to control the heart rate
6. To prevent the heart rate from dropping too low when you are taking certain

7. Medications to treat a very fast heart rate

Who is a Candidate for Cardiac Pacemakers?

Doctors recommend pacemakers for a number of reasons. The most common reasons are bradycardia and heart block. Bradycardia is a slower than normal heartbeat. Heart block is a problem with the heart's electrical system. The disorder occurs when an electrical signal is slowed or disrupted as it moves through the heart. Heart block can happen as a result of aging, damage to the heart from a heart attack, or other conditions that interfere with the heart's electrical activity. Certain nerve and muscle disorders also can cause heart block, including muscular dystrophy.

Doctor also may recommend a pacemaker if:

1. Aging or heart disease damages your sinus node's ability to set the correct pace for your heartbeat. Such damage can cause slower than normal heartbeats or long pauses between heartbeats (as discussed above). The damage also can cause your heart to alternate between slow and fast rhythms. This condition is called sick sinus syndrome.

2. You've had a medical procedure to treat an arrhythmia called atrial fibrillation. A pacemaker can help regulate your heartbeat after the procedure.

3. You need to take certain heart medicines, such as beta blockers. These medicines may slow your heartbeat too much.

4. You faint or have other symptoms of a slow heartbeat. For example, this may happen if the main artery in your neck that supplies your brain with blood is sensitive to pressure. Just quickly turning your neck can cause your heart to beat slower than normal. If that happens, not enough blood may flow to your brain, causing you to feel faint or collapse.

5. You have heart muscle problems that cause electrical signals to travel too slowly through your heart muscle. (Your pacemaker may provide cardiac resynchronization therapy for this problem.)

6. You have long QT syndrome, which puts you at risk for dangerous arrhythmias.

Children, adolescents, and people who have certain types of congenital heart disease may get pacemakers. Pacemakers also are sometimes implanted after heart transplants. Before recommending a pacemaker, your doctor will consider any arrhythmia symptoms you have, such as dizziness, unexplained fainting, or shortness of breath. He or she also will consider whether you have a history of heart disease, what medicines you're currently taking, and the results of heart tests.

How do Cardiac Pacemakers Work?

Pacemakers consist of two major parts:

1. **The Generator**: is essentially a tiny, hermetically sealed computer – along with a battery to run it – housed in a titanium container. Most modern pacemaker generators are roughly the size of a 10 Rupee coin piece, and approximately three times as thick. The battery life of most pacemaker generators today is 5 – 8 years.

2. **The lead**: is a flexible insulated electrical wire. One end is attached to the generator and the other end is passed through a vein into the heart. Most pacemakers today use two leads – one placed in the right atrium and the other in the right ventricle.

Functioning:

The pacemaker leads detect the heart's own electrical activity (in the right atrium and right ventricle,) and transmit that information to the pacemaker generator. The generator – which, again, is a computer – analyzes the heart's electrical signals, and uses that information to decide whether, when, and where to pace. If the heart rate becomes too slow, the generator transmits a tiny electrical signal to the heart, thus stimulating the heart muscle to contract. This is called pacing. Pacemakers that have two leads not only keep the heart rate from dropping too low, they can also maintain the optimal coordination between the atria and the ventricles (by pacing the atrium and the ventricle in sequence. Thus, pacemakers do not take over the work of the heart – the heart still does its own beating – but instead, pacemakers merely help to regulate the timing of the heart beat.

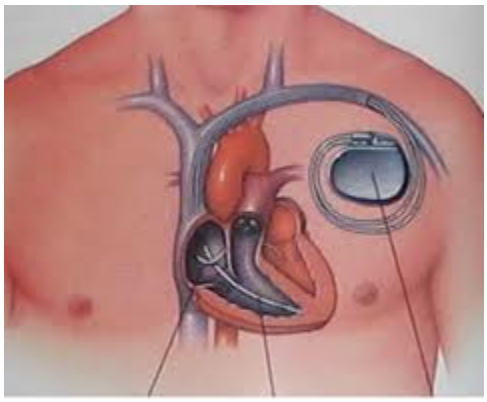
What are the Types of Cardiac Pacemakers?

There are two primary types of pacemakers:

1. **Standard pacemaker**: that triggers the chambers of the heart, and an internal defibrillator/pacemaker combination known as a cardioverter defibrillator. The standard type of pacemaker sends an electrical impulse via special wires that are attached to the heart. This replaces the signal that is sent by the heart, which is faulty in patients who need a pacemaker.

2. **The internal defibrillator/pacemaker combination**: these send an electrical impulse to the heart to control the heart's rate and rhythm, just as a standard pacemaker does. In

addition to that function, it can also deliver a “shock” to stop a “lethal rhythm,” a heart rhythm that does not allow the heart to effectively function. The idea of the shock is the same as the “shock with paddles” that you may have seen on television. However, because the device is attached to the heart with wires, the shock is much less powerful than what you may imagine.
The other types are as follows:



1. **Permanent (internal) Pacemaker** - these types of Cardiac Pacemaker is implanted in a small pocket under your skin and is meant to be left in there for the rest of your life.
2. **Temporary (external) Pacemaker** - these types of Cardiac Pacemaker is used for initial stabilization of the patient during a cardiac crisis.
3. **Demand Pacemaker** - These types of Cardiac Pacemaker has an inbuilt sensing device which senses when the heart beat is too slow and turns the signal on. Once the heart beat is above a certain level, it automatically turns the signal off.
4. **Single Chamber Pacemaker** - these types of Cardiac Pacemaker device has one lead to carry signals to and from one chamber of your heart, either the right atrium or, more commonly, the right ventricle.
5. **Dual Chamber Pacemaker** - these types of Cardiac Pacemaker has 2 leads and can monitor and deliver impulses to either or both of the heart chambers.
6. **Adaptive-Rate Pacemaker or Rate-responsive Heart Pacemaker** - these types of Cardiac Pacemaker automatically increases the pacing rate to meet the body's changing need.

What is the Diagnosis for Cardiac Pacemakers?

Patients being considered for Cardiac pacemaker implantation will undergo a full battery of cardiac tests, including an electrocardiogram (ECG) or an electrophysiological study or both, to fully evaluate the bradycardia or tachycardia. The symptoms of fatigue and lightheadedness that are characteristic of bradycardia can also be caused by a number of other medical conditions, including anemia. Certain prescription medications can also slow the heart rate. A doctor should take a complete medical history and perform a full physical work-up to rule out all non-cardiac causes of bradycardia. Patients are advised to abstain from eating six to eight hours before the surgical procedure. The patient is usually given a sedative to help him or her

relax for the procedure. An intravenous (IV) line will also be inserted into a vein in the patient's arm before the procedure begins in case medication or blood products are required during the insertion.

How to Prepare for the Cardiac Pacemakers?

The procedure used to put in this device is considered minor surgery. It involves numbing the site just under the tissue layers. You will be given a medicine in your IV to help you relax, but you will not be asleep. It is common to forget about the procedure or fall asleep during it. The procedure usually lasts between 45 minutes to 1 hour. You should not have food or water after midnight the night before the procedure. This prevents nausea and vomiting during the pacemaker placement.

What is the Procedure of Cardiac Pacemakers?

Surgery to implant a pacemaker is considered a minimally invasive procedure. It is not an open heart surgery, although it can be combined with an open heart surgery if necessary. The procedure is typically performed in an operating room or in a cardiac catheterization lab. Local anesthesia is given to numb the area of the chest where the procedure is performed, allowing the patient to remain awake while the surgery is performed without pain. In addition to numbing the area, a sedative may be given to help the patient relax or reach a twilight sleep state. Once the anesthesia takes effect, the chest will be prepared with a special solution to remove germs that may be on the skin, and the area will be covered with sterile drapes to keep the incision as clean as possible. The procedure begins with the insertion of the wires that attach the device to the heart. The wires are threaded through and into the heart where they are placed using a type of x-ray imagining that allows the doctor to see exactly where the wires are at all times. Once the wires are in place, an incision is made in the chest or abdomen, and the actual pacemaker device is placed under the skin. The wires, which are connected to the heart, are attached to the pacemaker. The pacemaker is then tested to make sure it is working effectively. Once the physician determines that the wires are in the correct place and the pacemaker is functioning properly, the incision is closed with sutures or adhesive strips and medication is given to wake the patient.

What to Expect after Cardiac Pacemakers?

Your nurse will discuss important aspects of your care with you before you go home. The following are very important:

1. You may have some mild discomfort at the insertion site. Your physician will provide a plan for pain relief.
2. Bandage the area over the pacemaker as directed and watch for any signs of infection such as elevated temperature, swelling, redness or drainage. If you notice any of these signs, notify your physician.
3. Do not do any heavy lifting or put any unusual stress on the arm and shoulder where the pacemaker is inserted. Your physician will tell you when it is safe to lift heavy items.
4. Your physician may tell you the pacemaker rate and ask you to take your pulse regularly. Notify the physician if your pulse is slower than the rate at which the pacemaker is set.
5. Call your physician if you develop shortness of breath or difficulty catching your breath, weakness, dizziness or unusual fatigue.
6. You will be given an educational booklet which also contains an identification card for your specific pacemaker.
7. Call your health care provider with any questions and remember to keep all scheduled appointments.

How will Cardiac Pacemakers affect your Lifestyle?

Once you have a pacemaker, you have to avoid close or prolonged contact with electrical devices or devices that have strong magnetic fields. Devices that can interfere with a pacemaker include:

1. Cell phones and MP3 players (for example, iPods)
2. Household appliances, such as microwave ovens
3. High-tension wires
4. Metal detectors
5. Industrial welders
6. Electrical generators

These devices can disrupt the electrical signaling of your pacemaker and stop it from working properly. You may not be able to tell whether your pacemaker has been affected. How likely a device is to disrupt your pacemaker depends on how long you're exposed to it and how close it

is to your pacemaker. To be on the safe side, some experts recommend not putting your cell phone or MP3 player in a shirt pocket over your pacemaker (if the devices are turned on).

You may want to hold your cell phone up to the ear that's opposite the site where your pacemaker was implanted. If you strap your MP3 player to your arm while listening to it, put it on the arm that's farther from your pacemaker. You can still use household appliances, but avoid close and prolonged exposure, as it may interfere with your pacemaker.

You can walk through security system metal detectors at your normal pace. You also can be checked with a metal detector wand as long as it isn't held for too long over your pacemaker site. You should avoid sitting or standing close to a security system metal detector. Notify airport screeners if you have a pacemaker. Stay at least 2 feet away from industrial welders or electrical generators. Some medical procedures can disrupt your pacemaker. These procedures include:

1. Magnetic resonance imaging, or MRI
2. Shock-wave lithotripsy to get rid of kidney stones
3. Electrocauterization to stop bleeding during surgery

Let all of your doctors, dentists, and medical technicians know that you have a pacemaker. Your doctor can give you a card that states what kind of pacemaker you have. Carry this card in your wallet. You may want to consider wearing a medical ID bracelet or necklace that states that you have a pacemaker.

Physical Activity: In most cases, having a pacemaker won't limit you from doing sports and exercise, including strenuous activities. You may need to avoid full-contact sports, such as football. Such contact could damage your pacemaker or shake loose the wires in your heart. Ask your doctor how much and what kinds of physical activity are safe for you.

Ongoing Care: Your doctor will want to check your pacemaker regularly (about every 3 months). Over time, a pacemaker can stop working properly because:

1. Its wires get dislodged or broken
2. Its battery gets weak or fails
3. Your heart disease progresses
4. Other devices have disrupted its electrical signaling

To check your pacemaker, your doctor may ask you to come in for an office visit several times a year. Some pacemaker functions can be checked remotely through a telephone call or a computer connection to the Internet. Your doctor also may ask you to have an EKG (electrocardiogram) to check for changes in your heart's electrical activity.

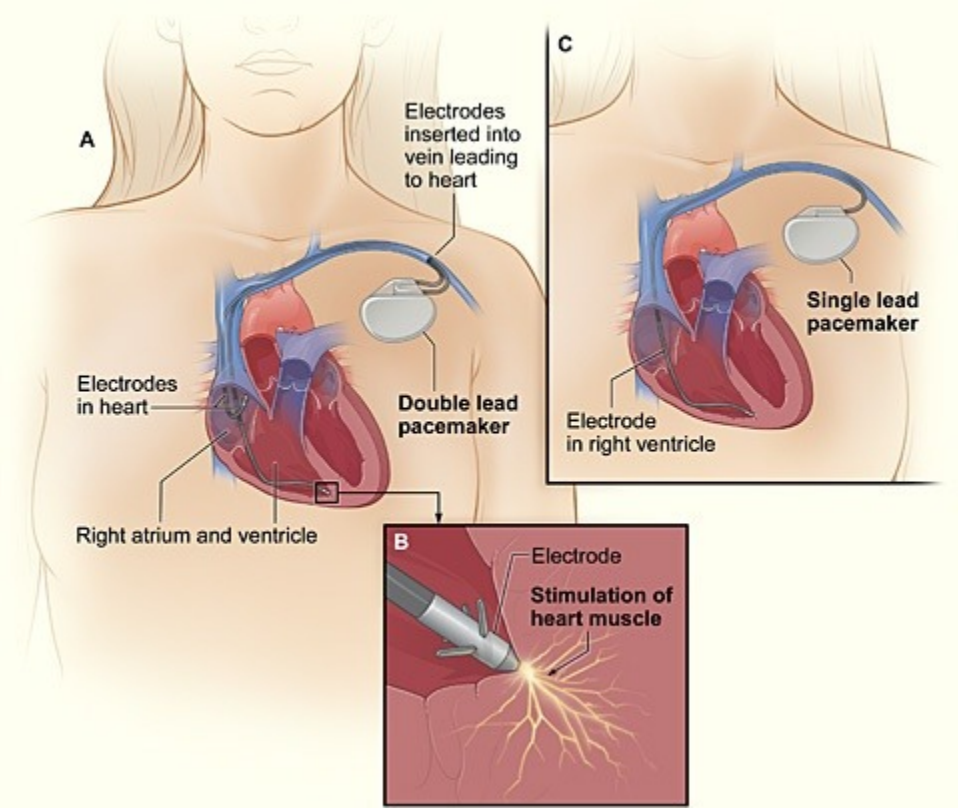


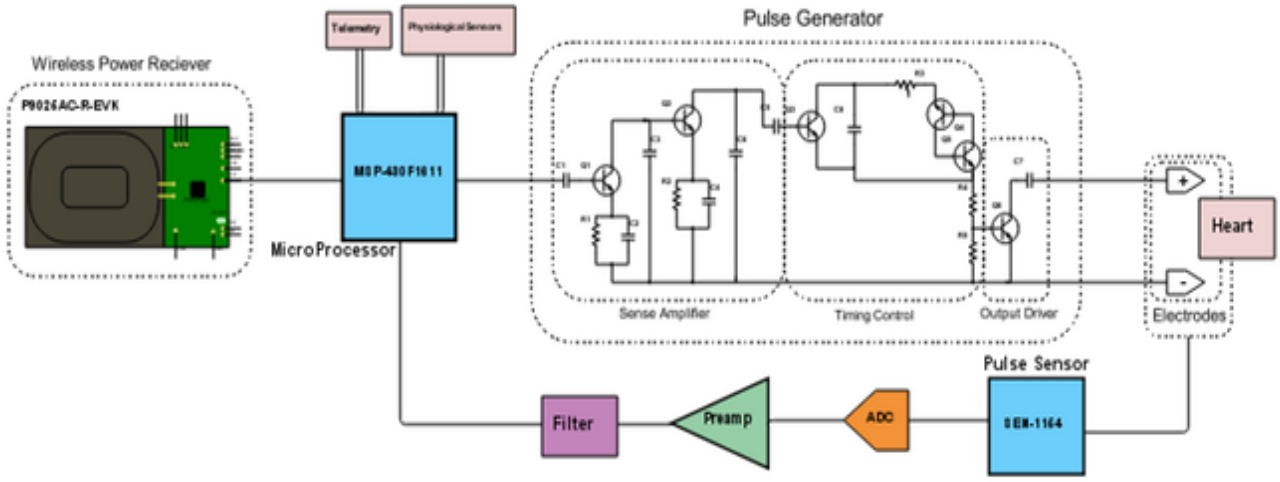
Fig: A typical arrangement of a pacemaker inside human body

Battery Replacement: Pacemaker batteries last between 5 and 15 years (average 6 to 7 years), depending on how active the pacemaker is. Your doctor will replace the generator along with the battery before the battery starts to run down. Replacing the generator/battery is less-involved surgery than the original surgery to implant the pacemaker. The wires of your pacemaker also may need to be replaced eventually. Your doctor can tell you whether your pacemaker or its wires need to be replaced when you see him or her for follow-up visits.

We deal with a Demand Pacemaker, which provides electrical heart-stimulating pulses only in the absence of natural heartbeat. When it was introduced in 1964, the Demand Pacemaker offered significant advantage over the previously-used pacing devices, which delivered a fixed-

rate pulse, thus competing with natural heartbeat and sometimes inducing ventricular fibrillation. The Demand Pacemaker also prolongs battery life because it is only activated when pacing stimuli are needed.

The Demand Pacemaker, connected to the IDT Wireless Power Receiver BoardP9025AC-R-EVK, is shown in Schematic Form.



Schematic Layout of a Demand Pacemaker

Making a Pacemaker Wireless

Since a Pacemaker is not easily available (a condemned machine is officially a bio-hazard) and is fairly expensive, we therefore represent here the most integral component of a Pacemaker: Its Pulse Generating Circuit.

A pulse generating circuit has to deliver electrical pulses at regular intervals of time. Such a circuit can be created as follows.

Step 1:Hardware Requirements

Material	Quantity
NE 555 Timer IC by Texas Instruments	X 1
LED bulb	X 1
0.01 µF Capacitor	X 1
10 µF Capacitor	X 1
330 Ω Resistor	X 1
270 kΩ Resistor	X 1
33 kΩ Resistor	X 1
Breadboard	X 1
IDT P9038-R-EVK - Qi 5W Transmitter	X 1
IDT P9025AC-R-EVK - Qi 5W Receiver	X 1
Jumper Wires	X 1

Step 2:Building up the working circuit

Connect the NE 555 to the breadboard. Note the orientation of the small IC using the notch at the top.

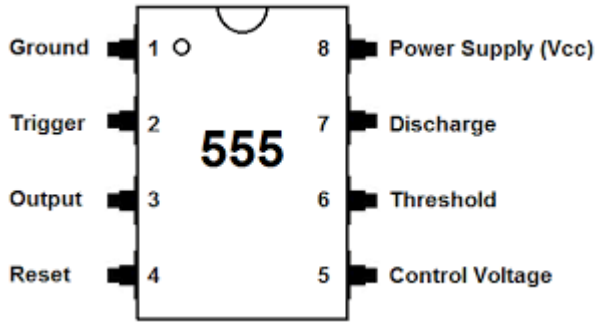


Fig: Layout of the NE 555 Integrated Circuit

(A) NE 555 IC and Receiver Board

Connect the Receiver board's OUT point to the NE 555's Power (8) and Reset (4) pins. Connect the Receiver's GND- terminal to the NE 555's Ground (1). Now connect the 0.01 µF Capacitor between the Ground (1) and Trigger (2) pins of the NE 555. This helps in regulating power flow into the IC and the initiation of the circuit.

(B) Resistors

Now connect the 270 kΩ Resistor between the +VCC (8) and Discharge (7) pins and the 33 kΩ Resistor between the Discharge (7) and Threshold (6) pins. Since I only had 90 kΩ and 22 kΩ resistors, I connected 3 90 kΩ resistors in series and a parallel combination of two 22 kΩ resistors in series with another 22 kΩ resistor to get the desired resistances.

(C) Capacitor

Next take the 10 µF capacitor; connect its positive terminal to the NE 555's Control Voltage (5) point and its negative terminal to the power sources ground terminal.

(D) LED Bulb

On this connection, attach a 330 Ω resistor which is connected to the negative terminal of the LED bulb. Connect the bulb's positive terminal to the NE 555's Output (3) pin.

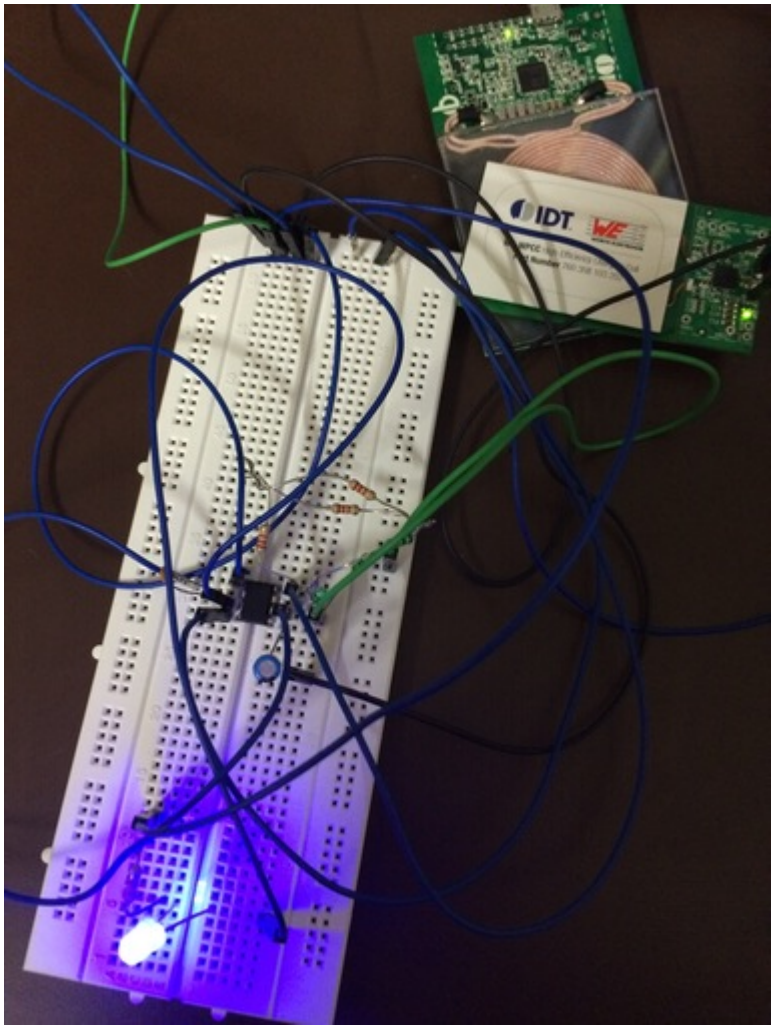


Fig: The typical Pulse generating circuit made by the configurations stated above

Step 3: Ready the Powering Mechanism

The Transmitter Board is plugged in through its Mini USB. As current flutters in through its coil, a green and a red light should come to life atop the board. Now when we take the Receiver Board close to the Transmitter ,at the correct relative orientation and distance between the two boards, an induction current would be set on in the Receiver's coil, thereby lighting an LED on board. The LED in the pulsating circuit would now begin to blink.

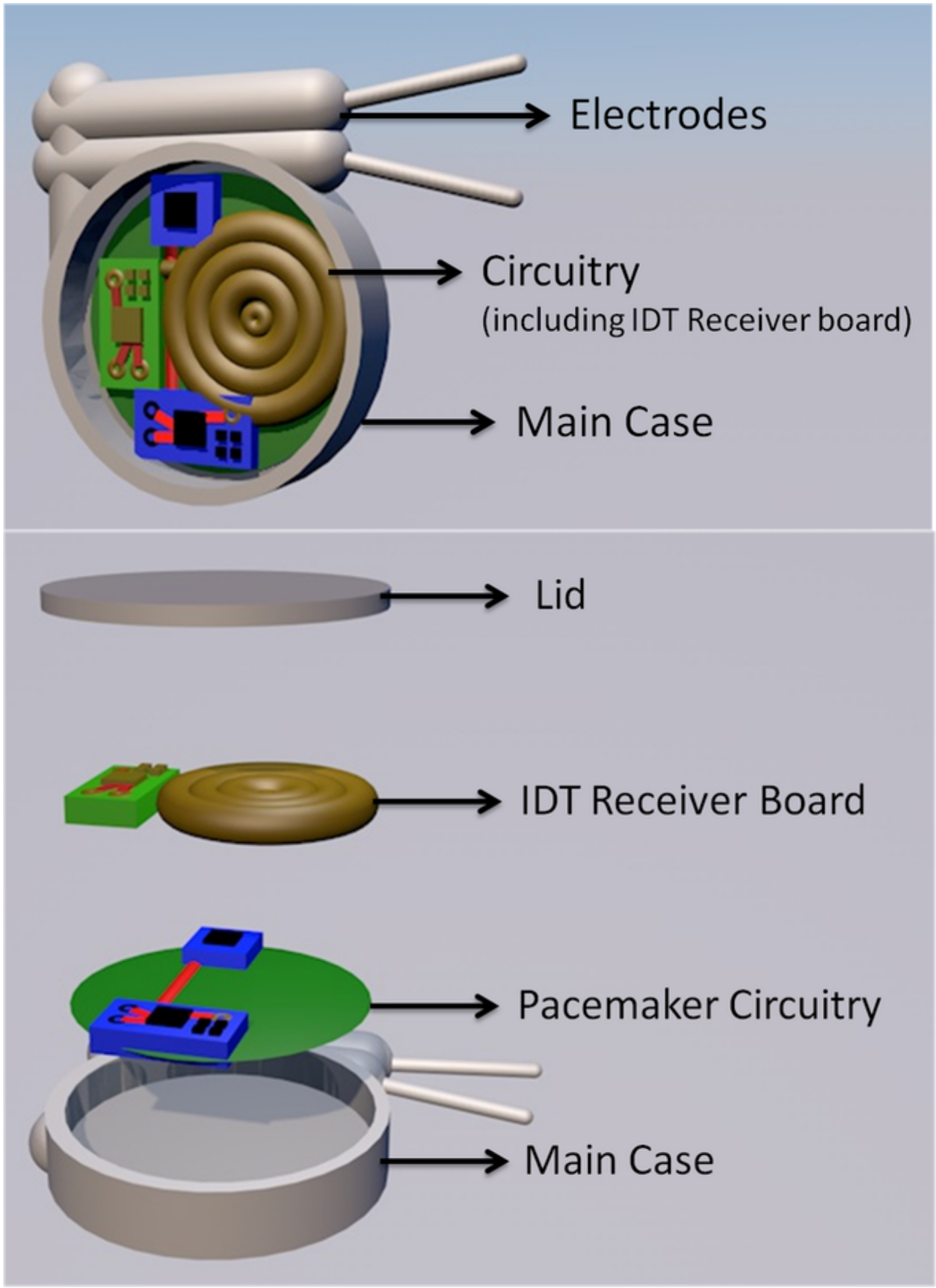
Step 3:Testing

In order to test the working of the system, take the Pulse Generator (with LED) and fasten it inside your shirt. Make sure to keep the back side of the Receiver board PCB away from the body.

List of components needed to make the final prototype

IDT Qi 5W Transmitter Prototype Kit	**X 1**
IDT Qi 5W Receiver Prototype Kit	X 1
Texas Instruments MSP430 Microcontroller	X 1
Resistor 330	X 1
Resistor 330 ohm	X 1
Resistor 270k ohm	X 1
Resistor 33k ohm	X 1
Capacitor 10 µF	X 1
Capacitor 0.01 µF	X 1
SparkFun Pulse Sensor SEN-11574	X 1
Jumper wires (generic)	X 1
Soldering iron (generic)	X 1

A proposed 3-D Model of the Pacemaker and how the various components fit in is given below.


Electrodes
Circuitry
(including IDT Receiver board)
Main Case
Lid
IDT Receiver Board
Pacemaker Circuitry
Main Case

This shows the various components of the Pacemaker circuitry and case, and how they combine to make a cohesive life-saving device.

Meanwhile, we are also developing the prototype on a PCB, so that we could able to get the appropriate desired model without much sophistication.

We believe that **Wireless Charging** would improve the life of the device, thereby reducing the need for replacing the existing device, which not only poses a risk due to surgery, but also creates additional bio-waste. Keeping the battery of the device fully charged would also result in an increased efficiency of the device.

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