Energy Harvesting IC for Illuminating Sights

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We saw several papers the last few days about new and emerging technologies. Most of them had electronics that needed to be powered. There were papers on Rifle sights, displays, range detection, fusing and safe and arm among them. Virtually all of these applications were powered by batteries. This paper will discuss the possibilities of using energy harvesting to power armament applications and demonstrate a prototype of a rifle sighting application.

What is Energy Harvesting?

- Vibration detection
  - Using transducer
  - Piezoelectric device
- RF energy
- Magnetic/Hall Effect

What is energy harvesting? It is taking energy that exists in the environment of the application and using it to power the application. A typical example would be a photo voltaic cell used in the sunlight to produce electricity. That might not be an ideal source for armament applications that need to work in the dark, but there are energy sources that exist virtually all the time. Simple applications have been around for a long time. One of the oldest examples of Energy Harvesting for a specific application is a crystal radio. It captures the RF energy of an AM radio transmission and uses it to convert the RF into an audio signal that can drive a headphone using some simple signal processing circuits.

One of best sources of energy is vibration which can be detected by a transducer or Piezoelectric device. It can be applied to a charge pump to generate DC voltage and current. Using this technique, unused energy can be used to power devices.

RF and magnetic energy can also be used in energy harvesting to power applications, but in most environments there is not enough energy to provide adequate power. They can be quite useful however in a subcategory of energy harvesting where the external energy is deliberately applied. A good example is RF ID tags like those in our passports. RF energy is applied by a tag reader, used to power the tag, and then used to read back the data on the tag.

Power Capabilities

- Maximum Voltage output 4 VDC
  - Internal Protection
  - Prevents damage to Silicon
- Typical current: 200μA
  - Limited by Input Source
  - Piezo wafers have greatest output

The typical power output from the harvesting system determines what kind of applications and how much additional circuitry can be powered. Typical voltages are up to about 4 volts and typical currents are up to 200uA. Limitations are both in how much power the transducer can provide and how much voltage the charge pump can accept. Integrated circuits have a maximum voltage rating and need to contain internal protection to prevent damage of the internal circuitry.

Analog Signal Processing Functional Capabilities

- Filters
- Op Amps/Comparators
- Multiplexors
- Data Converters
- Limiter/Companders
- Phase Locked Loop
- Analog Front End

So what kind of processing functions can be performed within these power constraints? Besides a charge pump and communications channel, these functions can be done with less than 200uA. There is not enough power to use a digital signal processor, but simple low power micro controllers can be used. These blocks could all be Integrated on a single energy harvesting chip.

There are examples of fairly sophisticated chips in the literature. A couple of companies have made medical processor IC's with charge pump, communications channel, input multiplexor, gain and an Analog to Digital converter. This is used with an external antenna and sensors to make a system that is implanted under the skin for remote reading of medical parameters such a glucose and body chemistry, demonstrating the ability to do quite significant applications with energy harvesting.

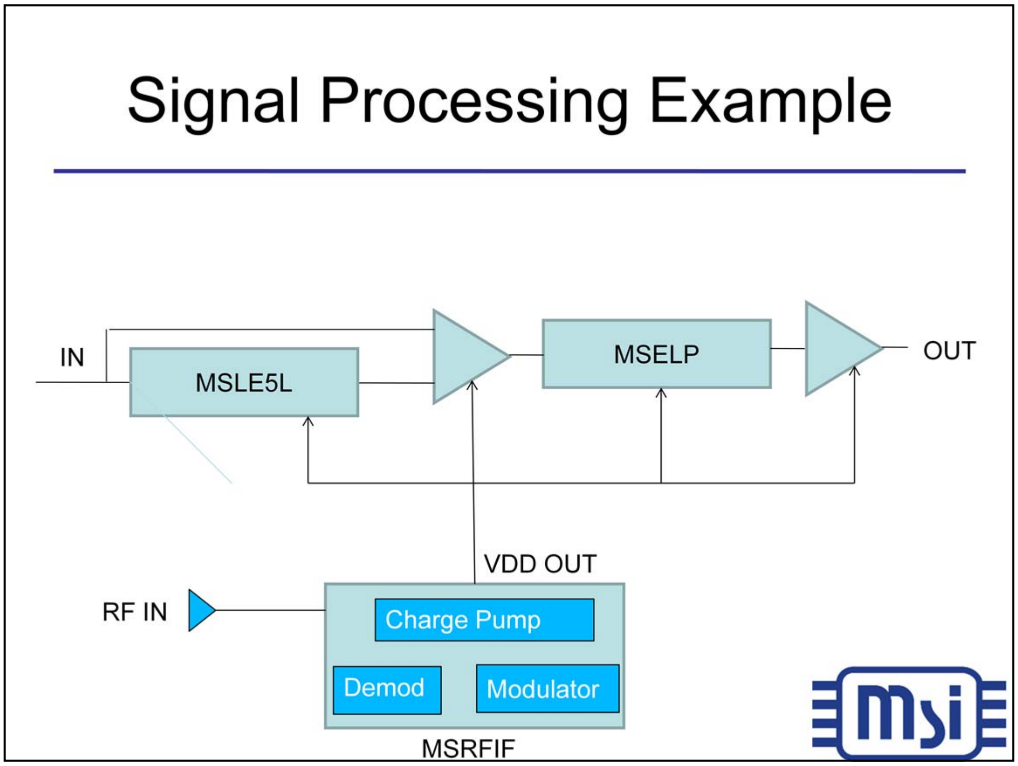
Applications

- Powering laser sights
- Illuminating red-dot sights
- Short range communications
- Remote programming

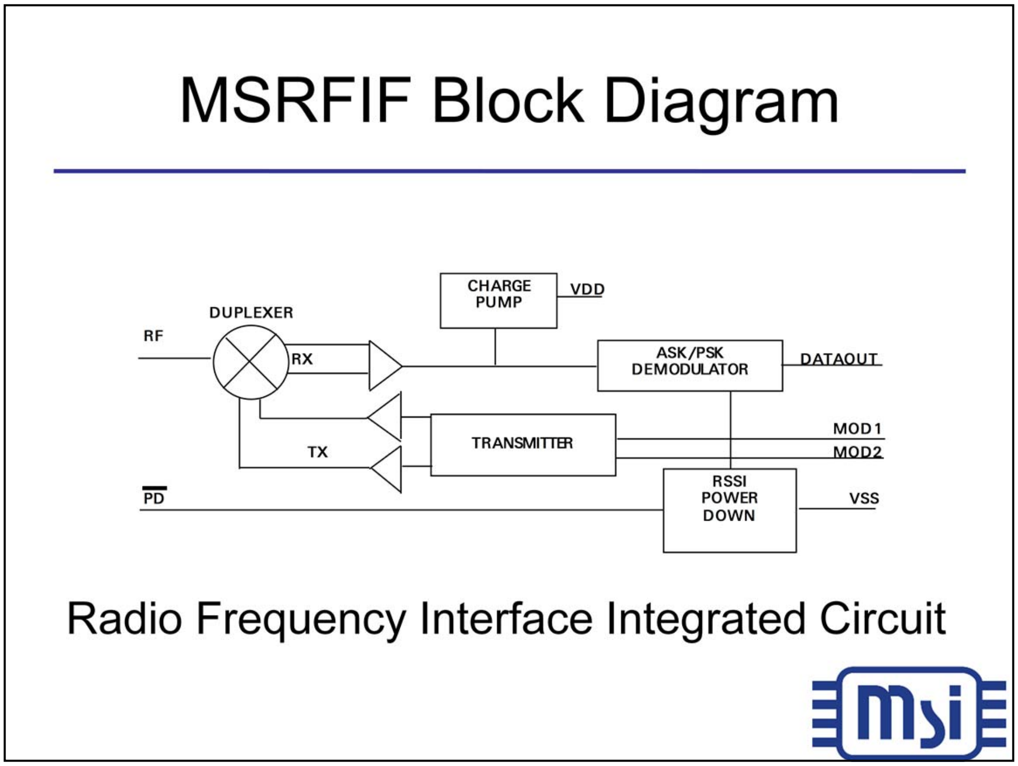
Here are some typical applications that have been prototyped with our energy harvesting device. Powering laser sights or illuminating red-dot sights is the application we will be demonstrating later. Short range communications such as Bluetooth or remote programming of munitions are also applications that have been prototyped.

We saw papers demonstrating smart munitions such as grenades and bullets earlier in the forum. One weapon that was described in a couple of papers was a less lethal 40mm low velocity round that blew up a flash bang up to 400 meters away. The arm time of a weapon like this could be programmed just before firing depending on the target, It the target was 100 meters the arm rime could be short. If we were firing over a crowd to a farther target, the arm time could be set longer to keep the round from exploding over the crowd..

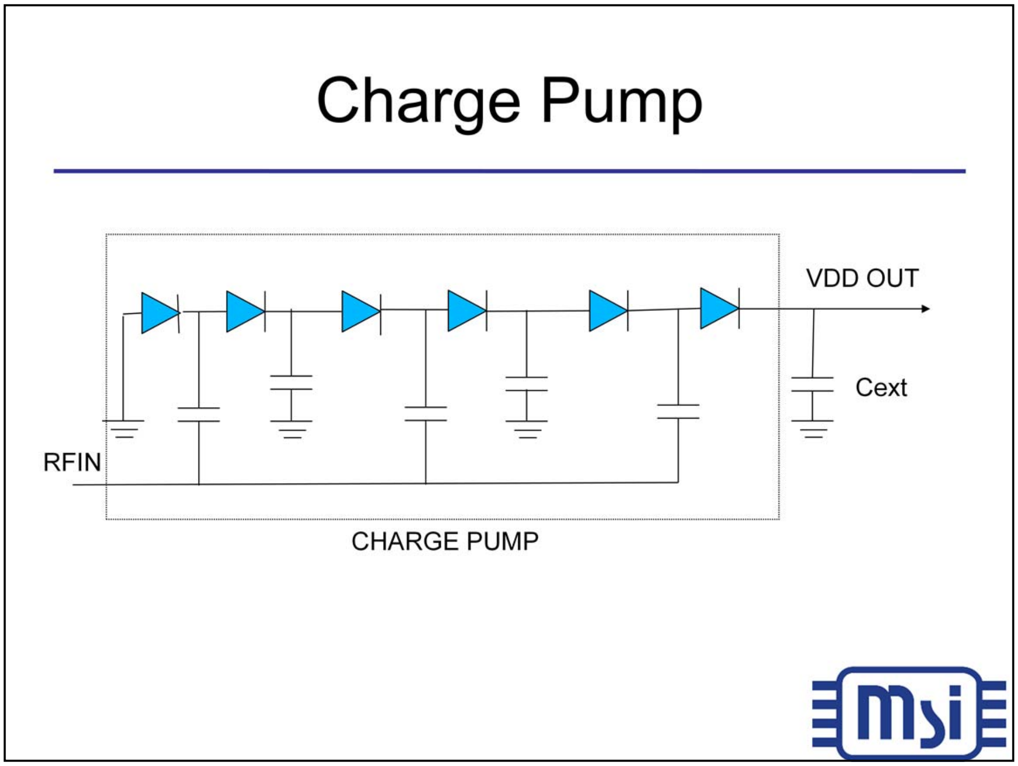
One of the issues of remote programming is hijacking of the device by another programmer. We all know the example of RF ID tags that can be read from 20 feet. We don't want somebody else 20 feet away programming the device. Since magnetic and RF both have square law characteristics, we can design the device to be powered by a programmers that is very close, less than an inch. If we needed one watt to program the device from an inch then it would take kilowatts to program from 10 or 20 feet, something that would be difficult to do.



Here is an example of a potential application. Using our standard products and our MSRFIF , a bandpass filter can be created. These building blocks can be integrated into a single integrated circuit. The MSLE5L 5th order Elliptic lowpass filter with an op amp from the MSELP will produce a highpass filter. The MSELP will provide a lowpass filter. The MSELP contains an RC operating mode which can clock both filters.

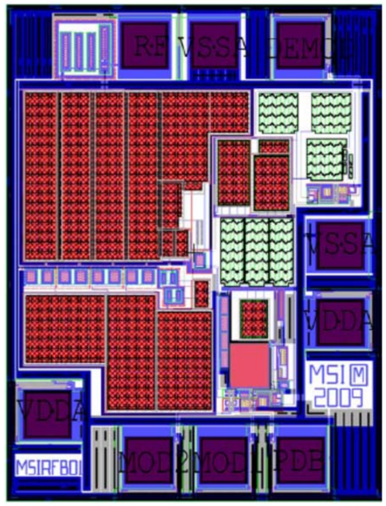


The MSRFIF provides the following functions: Charge pump that can convert from sub-audio frequencies up to RF into DC; an ASK/PSK demodulator and a power down indicator when VDD has not reached the correct value. The charge pump also includes a voltage clamp so the maximum voltage from the MSRFIF does not exceed 4 Volts. Also shown is the modulator for the received RF carrier, which can be used in RF harvesting applications. The MSRFIF also contains a Received Signal Strength Indicator to signal external controls that enough voltage exists for proper operation of signal processors.

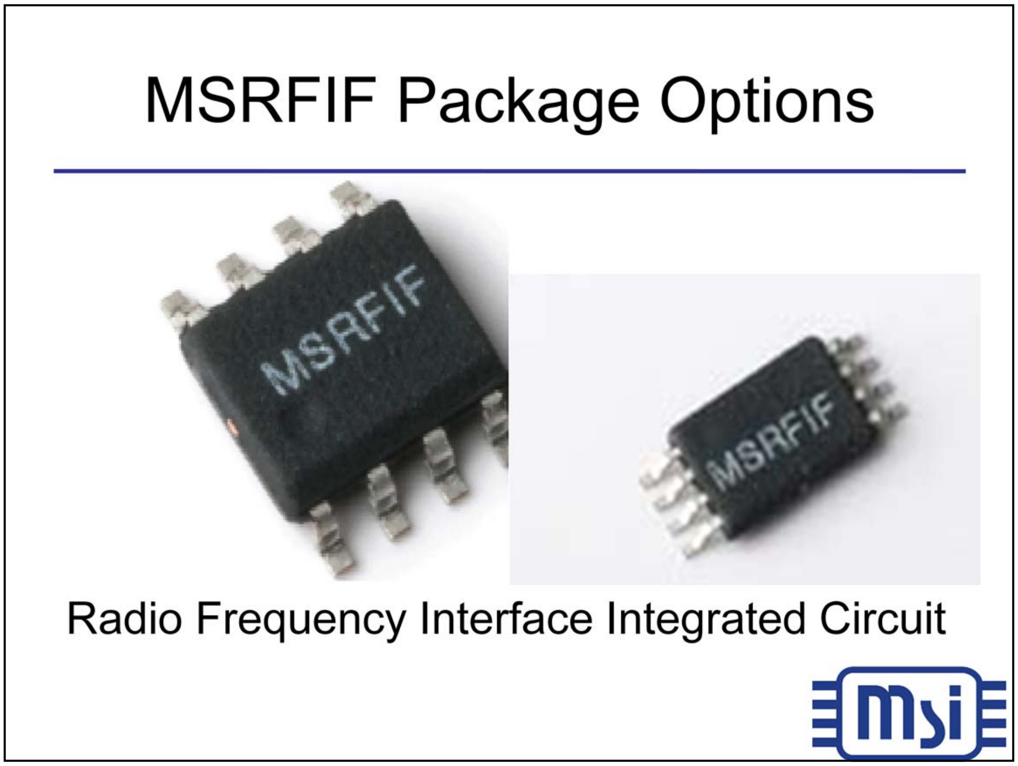


Here is an simplified block diagram of a charge pump. Using diodes and capacitors, received AC signals are rectified and filtered onto capacitors. The switching action of the transistor allows charge to be built up on the capacitor up to the voltage limit of the clamp diodes (4V).

MSRFIF Die Plot

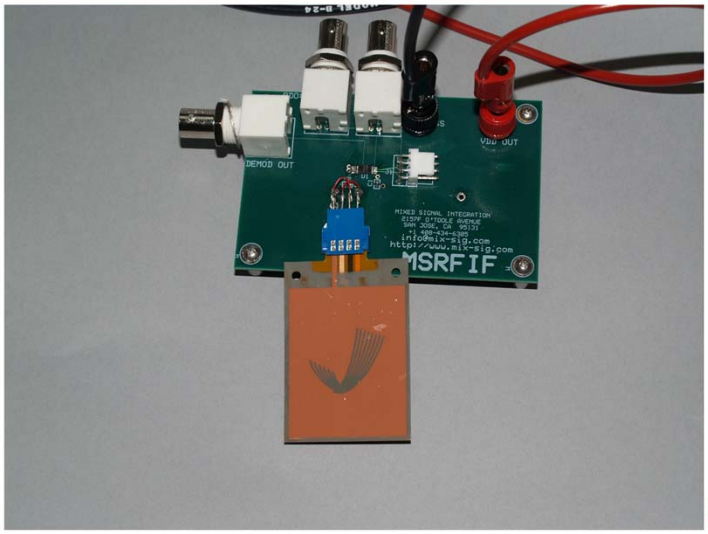


This plot is of the MSRFIF, showing the charge pump and filtering capacitors. The device is integrated in a 0.6 um double-polysilicon, double metal CMOS process.

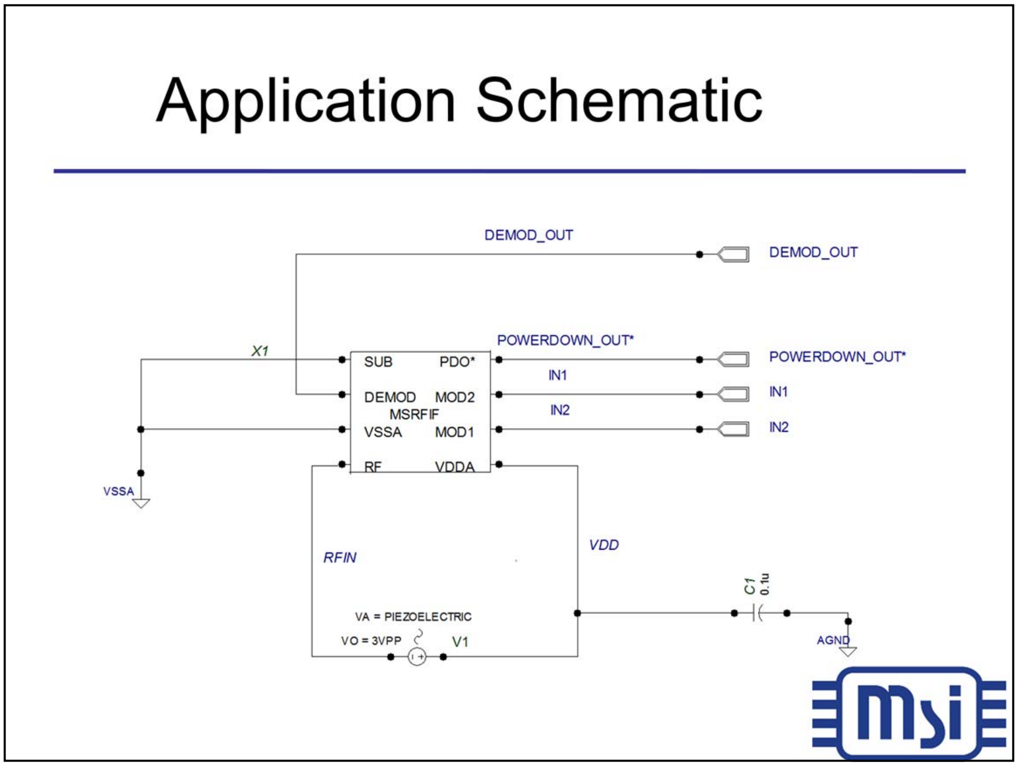


The MSRFIF is available in both a SOIC-8 package, 150 mils wide and a TSSOP-8 package 173 mils wide. The chips are almost always smaller than an Antenna or Piezoelectric transducer.

Energy Harvesting Application Board



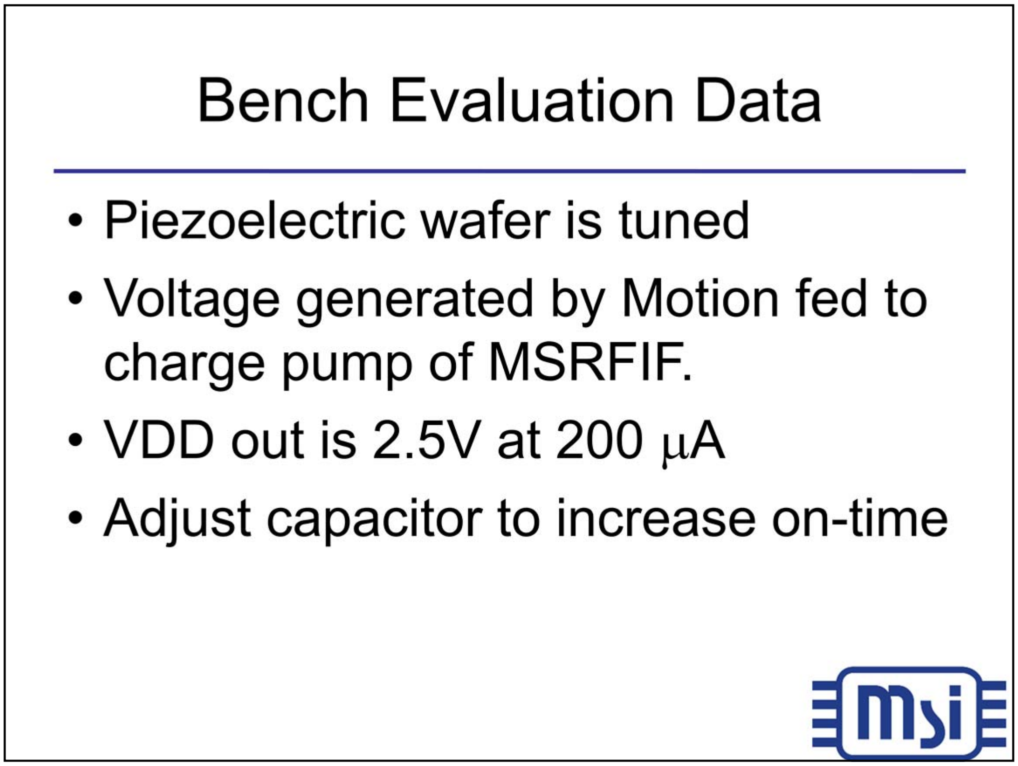
This photograph is of the MSRFIF evaluation board with Mide'Technology Center's Volture V25W piezoelectric wafer attached. The charge pump in the MSRFIF takes the input from the piezoelectric wafer and outputs DC to the binding posts. The MSRFIF is also capable of amplitude shift keying demodulation. If the vibration of the piezo device can be modulated, data can be demodulated by the MSRFIF.



This is a simplified schematic of the MSRFIF board. The Piezoelectric wafer is shown as a sine source, since the wafer will vibrate in a sinusoidal motion in most applications. VDDA is the DC output, tied to a filter capacitor. PDO will start out low, with no DC, then as 2V+ is achieved, will clamp low, indicating proper voltage for microcontroller's operation has been achieved. If the vibration has an amplitude shift keying (ASK) component, the DEMOD_OUT pin will show the data, up to the limit of the carrier frequency.

Red Dot Rifle Sight

This photograph is of the Truglo Red Dot Rifle Sight. This sight uses a CR2032 battery with a choice of either red or green dot and dot intensity. The CR2032 battery has the shortest life with the brighter red LED selected. With green LED selected the device draws 5 mA at its brightest setting.



The piezoelectric wafer is tuned to the resonant frequency expected by adding weight to the end of the wafer. The maximum for the large wafer is 120 Hz with no weight applied. The MSRFIF’s charge pump works down to less than 50 Hz, so, even if the tuned frequency is not reached, DC will be produced. The output current is then stored on a capacitor. Since the power source is dependent on the vibration, it is intermittent. The capacitor size is a design tradeoff depending on how long the sight needs to be powered and how much time is available to charge up the capacitor.

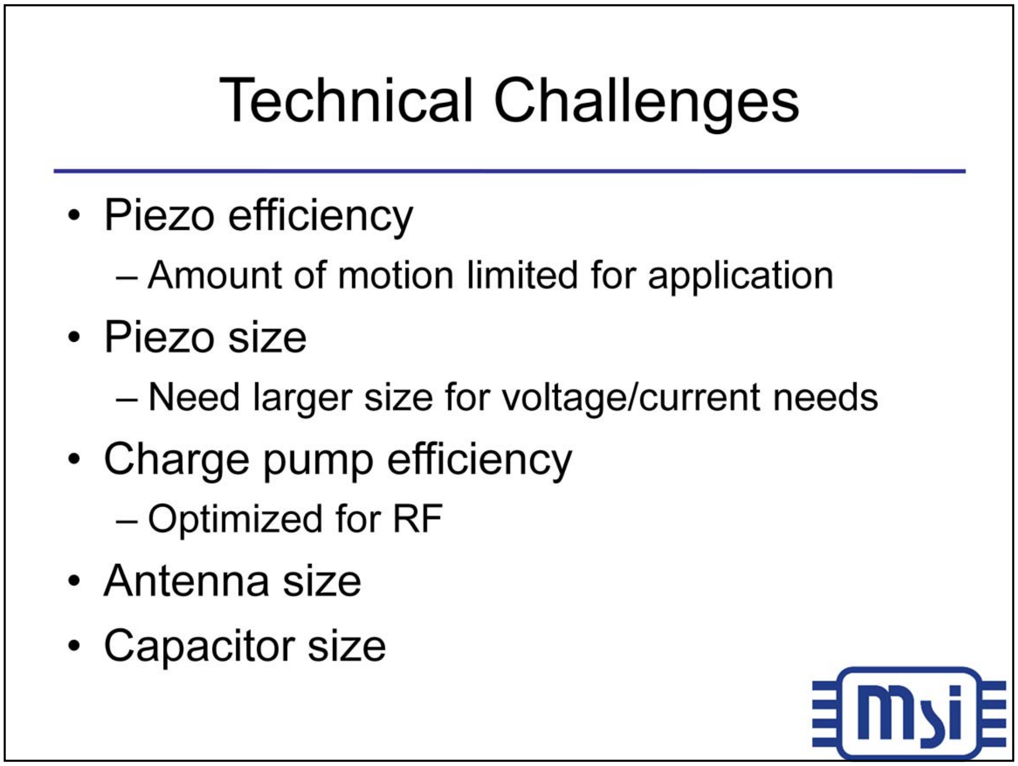
The Volture piezoelectric device outputs the greatest voltage and power at 40 Hz. At that frequency, the output expected is 1 mW at 3V.

Other Potential Uses

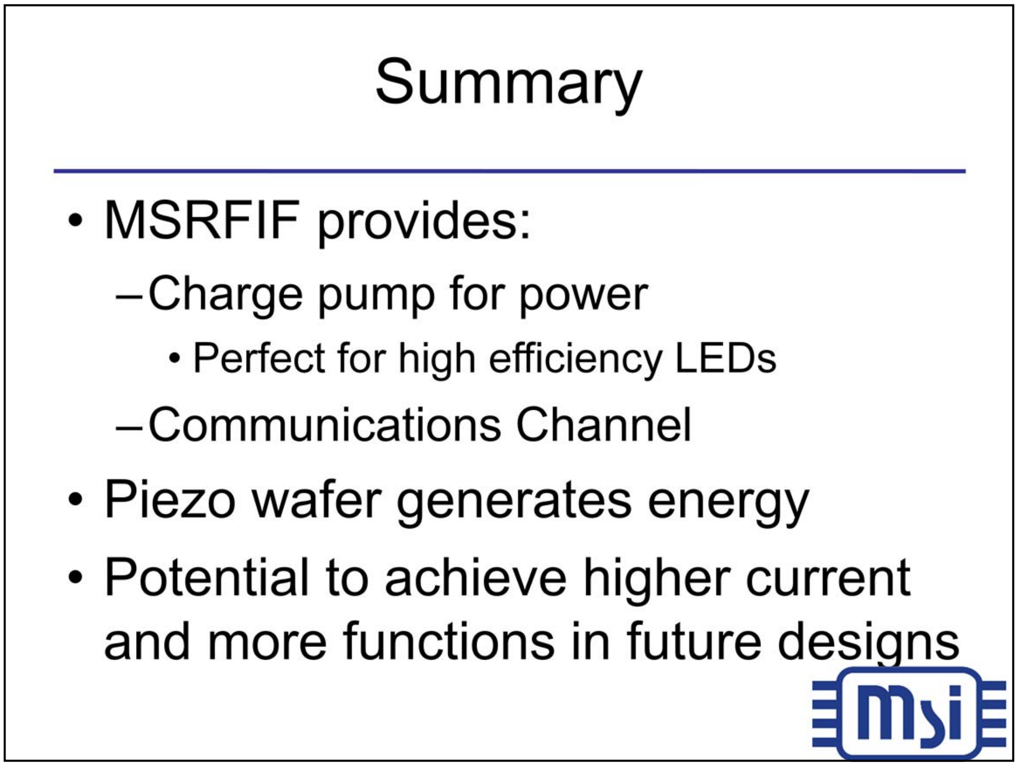
- Remote Programming
  - Safe and Arm time
  - Fuzing
- Bluetooth™

Other applications could be addressed if we added additional circuitry on the device. One example would be to include the Bluetooth communications device on the chip.. Another potential use for the MSRFIF is to add circuits for remote programming.

Another possible application for energy harvesting that was discussed in the ARDEC technology goals presentation was for field evaluation of head trauma. A piezoelectric device in the helmet could generate enough power to operate an electroencephalograph circuit that could monitor brain functions on the fly. Then after a traumatic event such as a nearby bomb or grenade or a fall, the data could be read out to see if the war fighter might need immediate medical attention.



The challenges with this present solution are the efficiency of the piezoelectric wafer and the size of the piezoelectric wafer. The motion needed to generate the 2+ volts is close to 1 inch. The size of the wafer is 2.3x1.6 inches. Finally the MSRFIF is optimized for radio frequency operation. The fact it works at much lower frequencies allows us to demonstrate the charge pump function. If integrated into a new design, the cells could be optimized for the lower frequency operation. In RF applications, antenna and capacitor size are a factor for space limitations.



The standard product MSRFIF provides a charge pump and demodulator for use in energy harvesting. With piezoelectric wafers, low frequency vibration will generate a DC voltage and current adequate for low current, high efficiency LEDs. This function could be integrated into a custom integrated circuit with other system blocks and achieve higher voltage and current.

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