What is a software defined radio?

A software defined radio is one where the RF signal is converted to a digital bit stream and all of the modulation and demodulation of the signal is done with digital signal processors (DSPs). An SDR performs significant amounts of signal processing in a general purpose computer, or a reconfigurable piece of digital electronics. The goal of this design is to produce a radio that can receive and transmit a new form of radio protocol just by running new software.

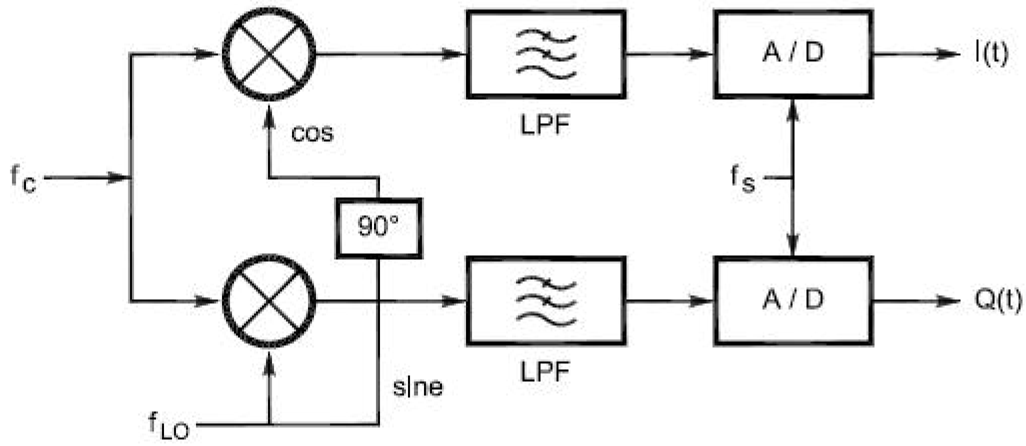
The SDR concept which led to the development of the first SDR experimenter's kit for ham radio was first described by FlexRadio Systems CEO Gerald Youngblood (K5SDR) in QEX during the summer of 2002. Gerald's four part article on the concepts and techniques used to develop the worlds first SDR for ham radio operators is still the quintessential primer on SDRs for ham operators.

1. A Software Defined Radio For The Masses Part 1; introduces DSP and how it is applied to SDRs along with describing a transceiver architecture.
2. A Software Defined Radio For The Masses Part 2; describes the initial software engineering needed to define a SDR.
3. A Software Defined Radio For The Masses Part 3; illustrates the use of DSP along with using a PC sound card to define a functional SDR.
4. A Software Defined Radio For The Masses Part 4; is a detailed description of the three board stack that was to become the ground breaking SDR-1000.

How are RF signals processed by a software defined radio different from a traditional receiver?

A software defined radio differs from a traditional radio in several ways. The biggest difference is in how RF is detected and demodulated. A SDR uses a **quadrature sampling detector** (QSD) that divides the incoming waveform into an in-phase or (I) signals and quadrature (Q) signal. The in-phase signal is the first 90º of the RF sine wave and the quadrature signal is the second 90º segment of the RF sine wave. Some simple math allows one to determine or recover the instantaneous phase and amplitude of the original signal. So, measuring the instantaneous values of I and Q, we would know everything we needed to know about the RF signal at a given moment in time.

In order for a sound card (the A/D converter) to digitize the incoming I and Q signal, the two signals are mixed with a local oscillator so that the resulting frequency is within the audio frequency (AF) range of the sound card known as the baseband signal. The resulting baseband signal is passed through a low pass filter to remove the unwanted image signals that are a result of the mixing products. Below is a block diagram of the process for converting RF (f_C) to digitized I and Q signals. The LPF and A/D converters are integrated into the PC sound card.



Once the I and Q signals are digitized, DSP algorithms perform all of the demodulation and signal enhancement eliminating the analog (and sometime digital) circuitry found in traditional radios which provide the same functions. Transmission is just the reverse of the RX process. There are no multiple IFs in a SDR. It is essentially a single conversion receiver, but the mixing of the LO to create a 0 Hz IF makes it appear a lot like a dual conversion receiver.

What are the advantages of a FlexRadio SDR over a traditional transceiver?

There are many differences:

- DSP code is not "fixed" in firmware.
- DSP Code is Open source. It is not proprietary
- DSP hardware can be upgraded easily
- New radio or operating features are easily implemented with a software upgrade
- Radio is constantly being improved. It never becomes obsolete
- Single step or conversion from RF to baseband audio
- Low noise due to eliminated multiple IF conversions
- Low distortion - distortion is introduced at every conversion stage
- Does not require roofing filters to improve performance
- 99% of the signal path is entirely in the digital domain

What are the major differences between a SDR and a traditional radio that I would immediately notice?

There are no knobs and buttons on the transceiver to manipulate. All of the radio control is done via software, so functions such as changing frequency, selecting filters, changing bands are no longer initiated on the radio hardware itself. The hardware is less complex due to the elimination of circuits that would normally be in a traditional radio which provide basic radio functions are now handled by the SDR software. Also, when very high quality A/D and D/A converters are used, an SDR will out perform all traditional radios on both transmit and receive.

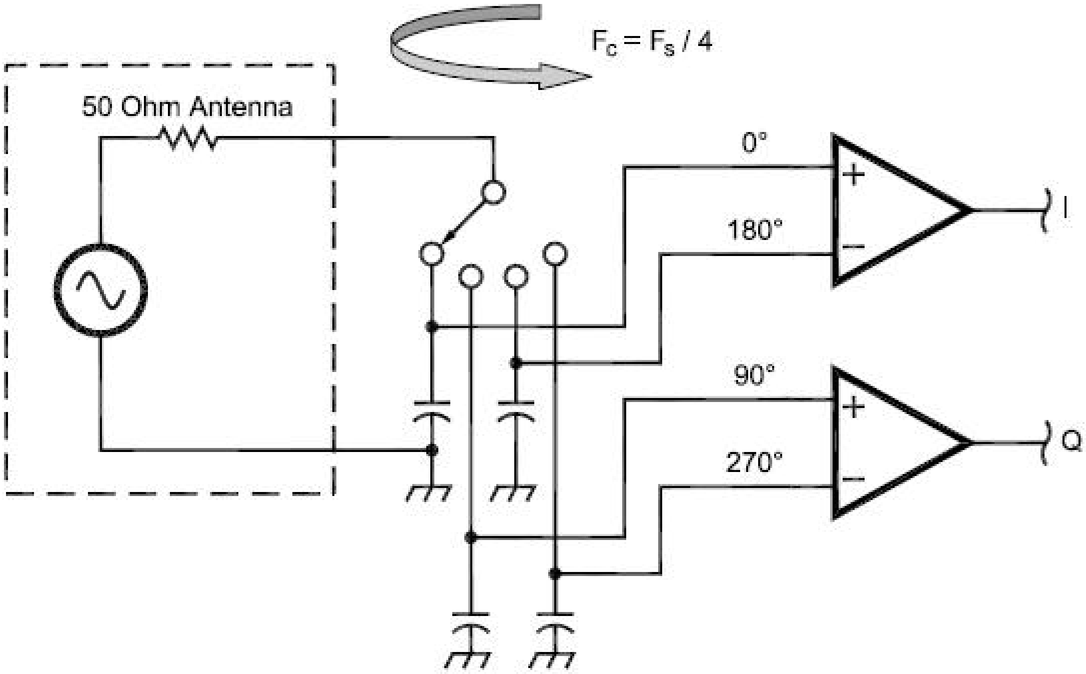
What is a quadrature sampling detector?

The quadrature sampling (QSD) or "Tayloe" detector, created by Dan Tayloe (N7VE) is a detector and preamplifier. Its features are based on an extremely compact and simple design. The device's feature set includes:

- Less than 1 dB of conversion loss

- A high third-order intercept (+30 dBm).

The basic product detector is shown below. Note the detector's simplistic design. The incoming RF signals are routed via a common resistor, *R,* and a commutating RF multiplexer, to one of four detection capacitors, *C*. This one-of-four multiplexer is commutated at a rate of four times the desired detection frequency. The 4x commutating frequency causes each capacitor to see a quarter cycle of the input RF at the desired detection frequency.



Mixers generally produce sum and difference outputs. In zero IF applications, the difference frequency is used, while the sum is thrown away. Therefore, the conversion loss using an ideal mixer is at least 3 dB, with a typical conversion loss of 4 dB to 6 dB in practice. Conversely, this design is not a mixer, but rather it can best be described as a "switching integrator," producing only a difference frequency. The input *R* and a particular detection *C* act together as an integrator, averaging the signal over the quarter cycle sample to the detection capacitor.

Performing an integration over the peak quarter cycle of this sine wave shows that the maximum detected voltage will be approximately 0.9002 times the peak voltage of the sine wave. Hence, the detection loss is about 0.9 dB. If the frequency of the incoming signal is shifted slightly from being exactly the detection frequency, the resulting voltages on the detection capacitors will no longer be stationary, but will drift with time, following the difference frequency between the incoming signal and the detection frequency.

In short, the first capacitor becomes a baseband product detector sampling at 0°, with the other detection capacitors detecting at 90°, 180°, and 270° degrees respectively. The 180° and 270° outputs carry information that is redundant with the 0° and 90° outputs. Therefore, the 0° and 180° outputs can be summed differentially to produce a single composite in-phase (I) signal and 90° and 270° can, likewise, be combined to form a quadrature (Q) signal. This differential summing can be performed using low-noise operational amplifiers (op-amps) or instrumentation amplifiers.

What is required from FlexRadio Systems in order to have a complete radio?

There are three basic components needed for a software defined radio; a computer, SDR software and hardware to convert RF into a digitized I and Q data streams. The computer and software have inter-dependencies in order to work together as a cohesive logical unit. For FlexRadio Systems products that would be an Intel or AMD based personal computer and a recent Microsoft Windows operating system such as XP or Vista. FlexRadio PowerSDR is the Windows based SDR software from FlexRadio Systems that is the second part of the computer/SDR software combination. Last but not least, is the SDR radio hardware needed to complete the triad of components necessary for a fully functional SDR solution. All three of these components together make up a functional SDR transceiver.