All Things Digital
Amateur Radio for the 21st Century
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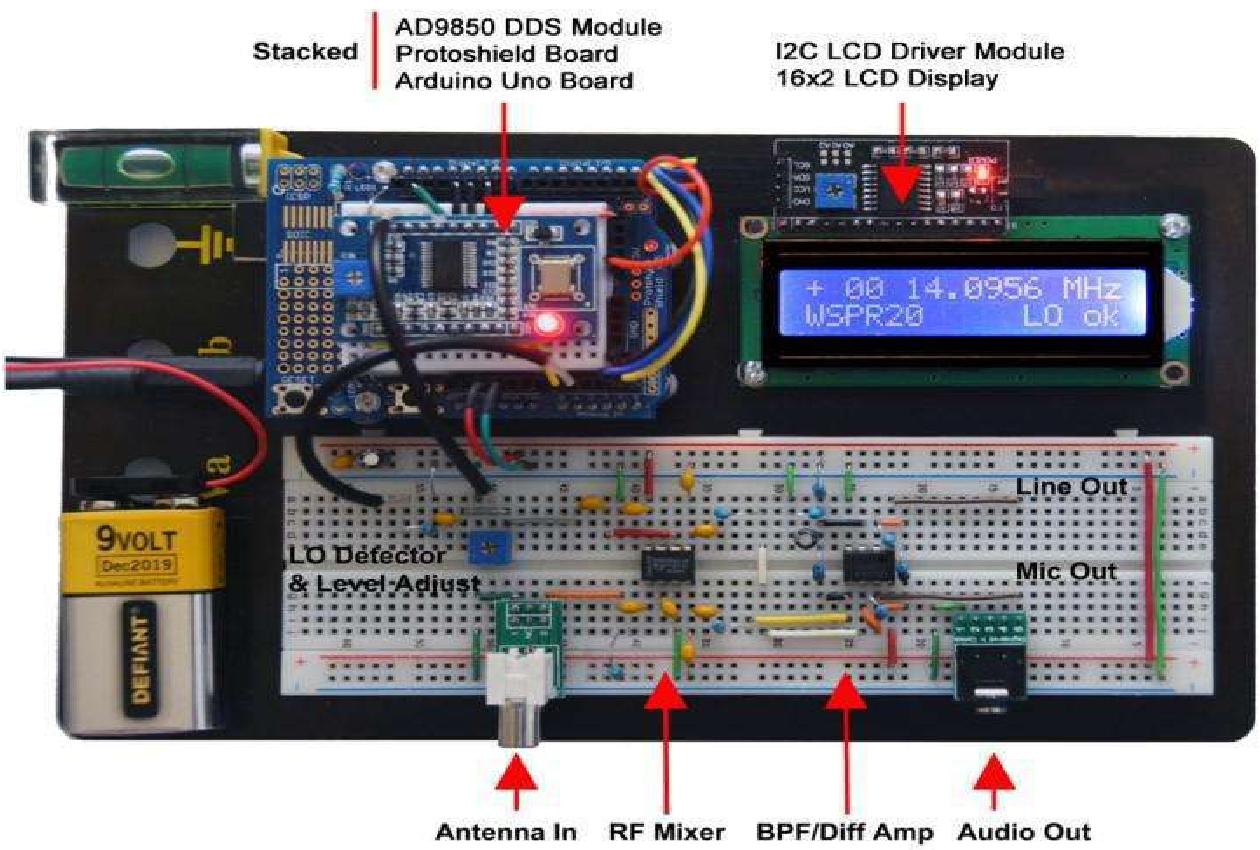
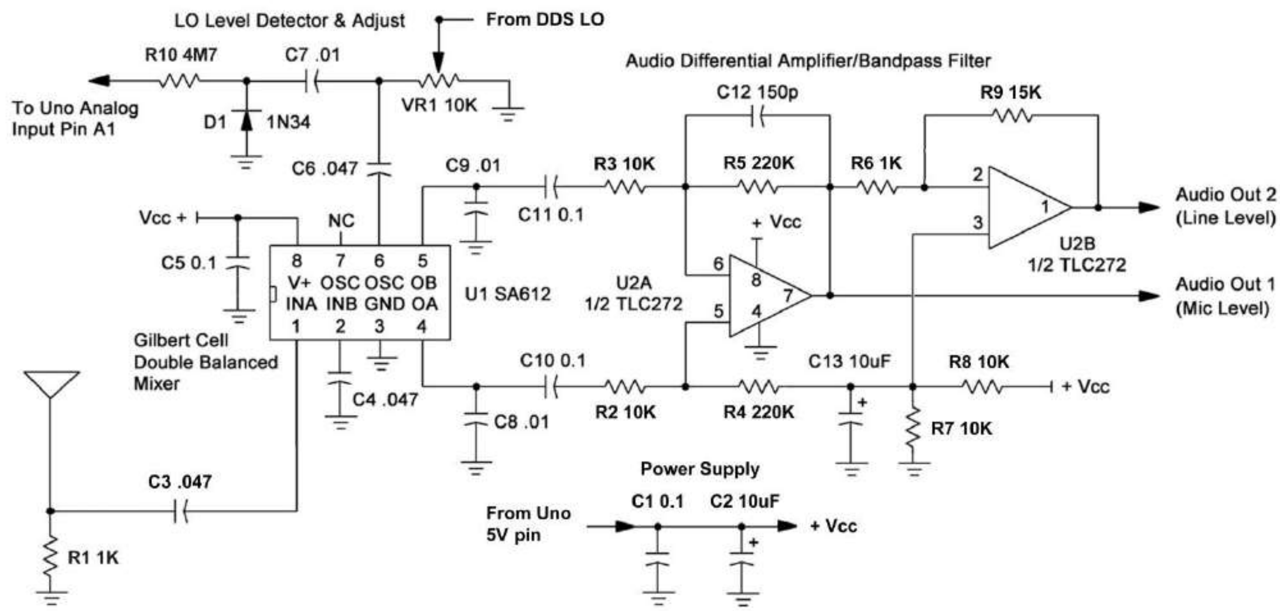
An Arduino DCR-SDR Project: Part 1

INTRODUCTION

In this part, we'll build a simple direct conversion receiver (DCR) software defined radio (SDR) using an Arduino Uno, a direct digital synthesis (DDS) AD9850 module, and liquid crystal display (LCD) plus free digital signal processing (DSP) software to decode various digital/analog data modes (image below and schematic next page).



This is based on the George Steber, WB9LVI, fixed frequency weak signal propagation reporter (WSPR) design from The Radio Whisperer (Nuts and Volts, Jan 2012); I've made minor changes to make it frequency agile and all-mode capable. The addition of an Arduino microcontroller unit (MCU) makes it extremely easy to modify and/or add enhancements to the hardware using the supplied program source code.

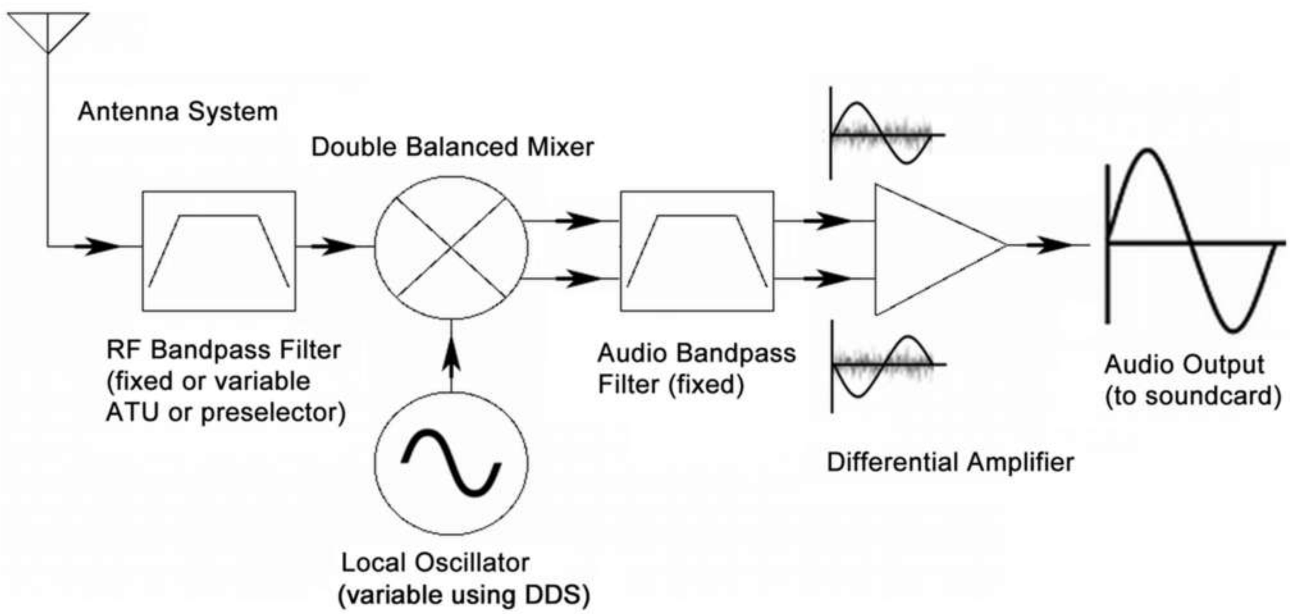


THE DCR IN DETAIL (image next page)

Note: I've overly simplified explanations and diagrams to avoid a lot of "techno-babel" and complex math.

1. **ANTENNA SYSTEM (ANTENNA + FEEDLINE)**
   Most of us think about antenna systems and how to connect/match them from the point of view of transmitters, and rarely think about it from the other point of view. But to a receiver, the antenna is the "transmitter" and the characteristic system input impedance is determined by the receiver (the "load"). Therefore, any voltage standing wave ratio (VSWR), impedance mismatch, or even antenna efficiency is unimportant for high frequency (HF) shortwave radio reception (3 MHz to 30 MHz) because the limiting factor is always the receive signal-to-noise ratio (SNR).

A non-resonant antenna system has little impact on receive performance because any losses within the system equally affects both the intended radio signal and the noise so there's no reduction in the relative SNR. Modern receivers have more than enough gain (sometimes too much) to make up for losses unless they are extreme in the first place. When combined with DSP software, it's now possible to decode signals with very negative SNRs down to -28 decibels (dB) in the case of WSPR. Note: An SNR of 1:1 (equal signal and noise levels) is defined as 0 dB.



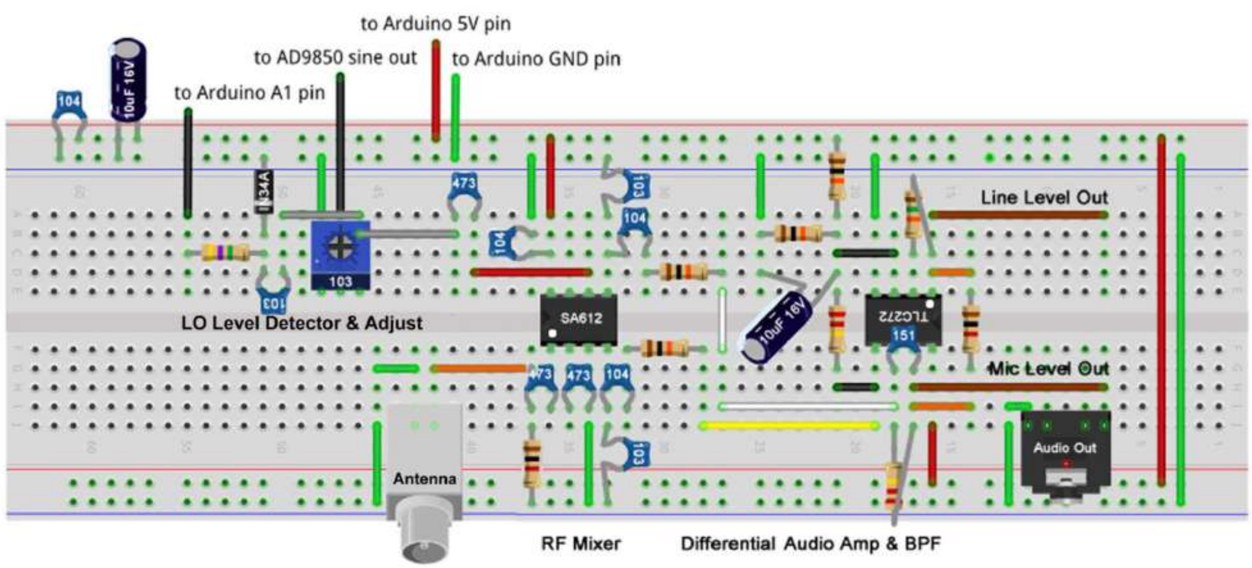
2. **BANDPASS FILTER**

In a receiver, the bandpass filter (BPF) allows radio frequency (RF) or audio frequency (AF) signals within a specific range (bandwidth) to pass through easily while attenuating/blocking signals outside of its designed "passband". It improves the SNR, receive sensitivity, and reduces [any] out-of-band interference. A BPF is especially essential for broadband receivers like simple DCRs because of their limited dynamic range, high sensitivity, low selectivity, and tendency to overload easily.

3. **LOCAL OSCILLATOR**
   A local oscillator (LO) generates a second RF signal, fed along with the antenna's incoming RF signal into a [non-linear] "mixer". Simple DCRs use a fixed or [slightly] variable crystal controlled oscillator (VXO) but the trend today has shifted towards using DDS modules. Most digital/analog data modes have been standardized and "channelized" using fixed dial frequencies, and transceive using USB mode (regardless of band) which also has greatly simplified things. E.G.: To receive 20m analog slow-scan television (SSTV) signals just tune the LO to 14.230 MHz (the dial or carrier frequency; for 20m WSPR tune to 14.0956 MHz. The DCR receives upper and lower sideband (USB/LSB) signals equally well, which is both a blessing and a curse for Morse code operators because two signals are generated and heard above and below the LO dial/carrier frequency!).
3. **MIXER**
   The very popular and versatile SA612 is a "Gilbert cell" double-balanced mixer, amplifier, and oscillator. We "feed" the mixer radio signals direct from the antenna system to only one of its two inputs ("unbalanced" mode) to allow operation over a wider range of frequencies from one antenna system (no RF BPF). It mixes the incoming radio signals with the LO signal we provide (non-linearly) to create the algebraic product or sum (another RF signal) and the difference (an audio signal). This type of receiver is called a zero-intermediate frequency (0-IF) or direct (single) conversion receiver. Unwanted RF signals are removed by shunting them to ground while the "balanced" (two separate but identical) audio signals are passed on.
4. **DIFFERENTIAL AMPLIFIER + AUDIO BANDPASS FILTER**
   The TLC272 is a low-voltage, single power supply, dual operational amplifier (op-amp). It's used to create a differential amplifier (diff-amp) with an audio BPF to remove noise from the audio signal, then amplify it for either soundcard microphone level input (laptops/tablets) or for to soundcard line level input (desktop computers).

One audio signal enters the diff-amp's "non-inverting" input (+SIGNAL + NOISE) and a second (identical to the first) goes into the "inverting" input and is made differential or inverted/phase-shifted by 180 degrees (-SIGNAL + NOISE). Atmospheric noises is random and can't be easily phase shifted because it has no specific pattern, but any data signals (including voice) do have predictable and repeating patterns. The noise is identical (common) to both op-amp channels and is called "common mode". The diff-amp "subtracts" signals (+SIGNAL - -SIGNAL = +SIGNAL + SIGNAL) and amplifies this "difference". Because the noise is common not different it's rejected (+NOISE - +NOISE = 0) and is called the "common mode [noise] rejection ratio" (CMRR).

Note: The audio output is connected directly to the soundcard's input (no coupling capacitor used) and the DCR/soundcard/computer grounds are connected or "tied" together via a mono/stereo audio cable. Use one as short as possible with good copper shielding (no dollar store stuff).



BUILDING/TESTING THE DCR

Note: The DCR circuit is simple, straightforward, and very easy to build on a standard solderless breadboard (image above) even for newbies and/or students. The MCU and DDS will be added in the part two article.

Note: Power the DCR using a 4.5 to 6V DC battery pack, or you can use a 9V battery by replacing the SA612's power lead (red wire) with a 100 ohm (¼ watt) resistor.

To test the DCR, you'll need an RF signal generator to provide the LO signal for the mixer. To set the proper LO RF voltage for the mixer, measure the DCR's direct current (DC) voltage from R10 to ground with a digital voltmeter, and adjust VR1 to set the level between 200-300 millivolts (mV). Connect the antenna, and use the RF signal generator LO to "tune" to WWV (5, 10, or 15 MHz). Connect an audio patch cord from one of the DCR's audio outputs to the appropriate computer soundcard input, and adjust audio levels as required. If you don't hear the familiar time signal from your computer's speakers something is definitely wrong!

MY FINAL

Part 2 explains what DDS is and how it works. Then we connect the Arduino Uno MCU plus AD9850 DDS module to the DCR circuit to complete the final assembly and you can do the basic testing then—if you prefer. Free DSP software lets us see what we can see (literally) and optionally lets us stream and share our captured and processed data with others in cyberspace.—73

REFERENCES AND RESOURCES

Bandpass Filter
http://en.wikipedia.org/wiki/Band-pass_filter

Differential Amplifier
http://en.wikipedia.org/wiki/Differential_amplifier

Direct Conversion Receiver
http://en.wikipedia.org/wiki/Direct-conversion_receiver

Frequency Mixer
http://en.wikipedia.org/wiki/Frequency_mixer

The Radio Whisperer (PDF)
www.kc4zvw.org/files/wspr-receiver.pdf

VA3ROM: All Things Digital
http://tinyurl.com/og2acxq