CTCSS Tone Encoder using the PIC12C508A

By John Kent - VK3BIZ

Tony Hunt, VK5AH, has written a PIC CTCSS tone encoder for the Microchip 16F84.
http://users.picknowl.com.au/~wavetel/pic.htm

It uses a square wave output to generate the tone with 16 bit counter and 8 bit correction factor to generate the correct frequency. The problem with this approach is that there are a lot of odd order harmonics generated in the audio voice band that are difficult to filter out.

Filtering 3rd order and 5th order harmonics of a square wave around 300Hz and 500 Hz with a first order RC filter would only give about 9.5 dB and 14 dB attenuation respectively with a first order RC filter.

Chuck Olson, WB9KZY, has written a tone generator using the 16F84 and a 20K R-2R resistor ladder as a Digital to Analog converter. He generates a sine wave from a 64 entry look up table. His code and utilities for generating the sine table are available on YO5OHF's web site:
http://www.qsl.net/yo5ofh/pic/tonef84/

What I wanted to do was use an 8 pin PIC12C508, to keep the size and the cost down but because of the limited number of pins, I had to come up with another scheme for generating an analog signal.

I used a PWM (Pulse Width Modulator), written in software, as the Digital to Analog converter and I modulated that with a sine wave generated by a 64 entry look up table to generate the tone, similar to Chuck Olsen's (In fact I used his sine table). The idea of the PWM is that by changing the duty cycle of the pulse you can produce a varying low frequency voltage. An RC filter on the output filters out the high frequency components of the PWM pulse.

The PIC12508A can run at 4 MHZ which means the instructions execute in 1usec or 4 clock cycles. The PWM cycle takes roughly 250 instruction cycles to generate a 65 step PWM output. This means that the PWM cycle is around 4KHz, which is well above the CTCSS tone frequency, making it easier to filter out.

For each PWM cycle, a phase offset is added to a 16 bit phase accumulator, the top 6 bits of which are used to index into a 64 entry sine wave table. Using a 16 bit phase accumulator means that the frequency of the tone is accurate to 1 in 65536 or 0.0015%.

A 10 K resistor in the output with a 0.1uF capacitor results in a 160Hz low pass filter. The 4KHz PWM square wave can be attenuated by 28 dB, which is not terrific but is still better than trying to attenuate 3rd order and 5th order harmonics of a square wave.

There is an issue in this design with the quantization noise. Although the PWM has 6 bit resolution, the phase accumulator increment varies from 1/45 to 1/32 of the sine cycle depending on the tone frequency so there is a lower frequency noise component around 2KHz to 3KHz however this should be 30 dB down on the CTCSS tone.

The 12C508 has 2 tone select bits and a tone enable bit that allows you to select between 1 of 4 tones. The two tones most commonly used on Australian VHF and UHF repeaters are 91.5 Hz and 123.0 Hz. If the design was implemented on a 16F84 it would be possible to generate a wider range of tones using the extra port pins to select the tone however this is a bit of an over kill for Australian amateur repeater use.

Using the 8 bit R-2R network on the 16F84 would allow the sampling frequency to be increased to around 16 KHz which would allow better high frequency noise attenuation. You would however be limited in the tone set by the number of free pins left on the PIC16F84.

The FM900 outputs a 6(?) or 8(?) bit code from the NSC810 to select the CTCSS tone from the CML CTCSS chip. It is not necessary to use all the tones, so it should be possible to only use only a subset of the tone select pins for the 12C508 CTCSS encoder.

I have put the software up on my web site. http://members.optushome.com.au/vk3biz/ctcss-tones.html . The tone constants may need slight tweaking to get them spot on frequency as my Digital Frequency Meter only resolves down to 1 Hz and I have been unable to confirm if I have the frequency constants exactly right.

The output is in the order of 3V peak to peak. Further audio filtering is possible to attenuate the 4KHz component.

The PIC specification sheet suggests using 30 pF capacitors on the crystal oscillator. I didn't have any 30 pF caps on hand so I tried 47pf instead, but the oscillator did not work with the 4MHz crystal I had. I ended up removing the capacitors altogether on the breadboard and the PIC burst into life. I've shown 18 pF caps on the schematic for completeness however the design may well work better without them.

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