**QRSS Grabber**

QRSS is used by radio amateurs for transmitting slow Morse code from low-power transmitters and receiving them on special “grabbers.” This creative project features an mbed at the core of a QRSS receiver, which is an RF receiver that can digitize a small bandwidth of RF signals and send them to a server for processing into a spectrum image for real-time display on a website.

Clayton Gumbrell  
Australia  
clayton@gumbrell.net

---

**AC Tester**

Safety is a top priority when working with electronics and circuits. The AC Tester design is an isolated variable voltage power source that includes an electronic circuit breaker for testing and debugging equipment. An mbed controller displays voltage and current, and it controls the breaker’s trip point and response time. In addition, this inventive design can display power factor, VA, and VAR.

Kevin Gorga  
United States  
kgor@stny.rr.com

---

For complete projects visit:  
www.circuitcellar.com/ 
nxpmbeddesignchallenge
Sine Wave Synthesizer

If seasonal time changes cause your WWVB radio-controlled clocks to lose synchronization, building your own WWVB simulator is the first and necessary step for devising a remedy. With a few inexpensive parts, you can build a robust sine wave synthesizer as the heart of a WWVB simulator.

I have several WWVB radio-controlled “atomic” clocks. I never paid much attention to their inner workings except twice a year, during the seasonal time changes, when I noticed that some clocks would take several days to synchronize and others wouldn’t synchronize at all. If I adjusted them manually, some would jump an hour forward or back (weeks or even months later), depending on the season. It drove me crazy. I blamed the clock design, but I didn’t do anything about it. Until now.

After reading Ed Nisley’s articles on building a WWVB clock in Circuit Cellar issues 235, 237, and 239, it finally dawned on me that the cause of the sync problem had to be poor reception from the 60-kHz radio sync signal transmitted from Colorado. A few tests confirmed the carrier was buried in noise during the day and barely above noise at night. Consequently, successful reception was infrequent, only during the wee hours of the morning. I realized I needed a WWVB signal simulator before I could do any more work to rectify the situation.

TRANSMISSION & RECEPTION
I purchased a WWVB receiver module, a 100-mm long 60-kHz loopstick antenna, and a 60-kHz resonator from Digi-Key, all for less than $20. The first step to building the simulator was to generate a clean 60-kHz sine wave from the square wave output of the resonator-stabilized oscillator. I measured the Q of the loopstick antenna to be more than 120, so I didn’t really need to generate a sine wave. Tests confirmed that when driving the loopstick antenna with a 60-kHz square wave, higher harmonics were sufficiently attenuated to transmit an acceptably low-distortion sine wave. I planned to experiment with different transmission antennas—some with potentially low Q—at a later date, so it made sense to avoid later hardware changes and to design the modulator producing a sine wave carrier now. Since I was going to breadboard the circuit on a Vector board, I wanted a robust, digital design with high immunity to stray capacitances and only a few inexpensive components.

![Figure 1—The digital sine wave generator](image-url)
CIRCUITY

Years ago, after CMOS integrated circuits made their debut, I saw an interesting sine wave synthesizer that I often used at a later date. Other than a few flip-flops, it only needed several 1% resistors. I used that circuit in several projects to generate a linear variable differential transformer (LVDT) excitation signal of 3,200 Hz, low total harmonic distortion (THD) sine wave with excellent frequency and amplitude stability. It has worked on aircraft at temperatures from -40°C to 85°C with no additional compensation. I dug out my old design notes and Figure 1 is the circuit modified for 60-kHz output.

The circuit uses two 4013 dual flip-flops, three standard value 1% resistors, and one capacitor. It took me a few minutes to breadboard it and the result was impressive. With capacitor C1 removed, the input—that is, the clock (red trace)—and the output (blue trace), are shown in Figure 2.

The THD of the output staircase signal is about 20%. By adding C1, the staircase waveform turns into an approximately 500-mV_{RMS} (V_{CC} = 5 V) sine wave with 4.9% THD, as shown in Figure 3. At this point, I hasten to add that when it comes to embedded controllers, audiophiles' standards usually do not apply. I am not aware of any embedded control application...
where a 5% THD sine wave would not be considered a sufficiently low distortion.

Frequency stability of the 60-kHz sine wave depends on only the resonator stability, while the amplitude depends mainly on the power supply, provided a zero temperature coefficient capacitor C1 is used. A sharper low-pass filter could reduce the 4.9% THD, but, in my case, I couldn’t see a need for it. Other than the stable power supply, the temperature stability of the filter is the critical part of the design to ensure amplitude stability over a wide temperature range. Because I don’t plan on using the circuit outside of my workshop, the single zero temperature coefficient C1 works well. Figure 4 shows the spectrum of the sine wave with C1 in place. Table 1 lists the actual decibel levels of the first 10 harmonics. This is more than sufficient to drive the RF transmitter with a low Q antenna.

It is possible to design the synthesizer with more stages to reduce the level of the harmonic distortion. If you want to build more stages, remember that the last stage is always inverting the signal and has no resistor [see Figure 1]. If we normalize the resistor values [in Figure 1 the normalized value “1” corresponds to 12.1 kΩ], a six-stage synthesizer, for example, will have normalized values of 2.000, 1.155, 1.000, 1.155, and 2.000. The harmonic content will be significantly reduced compared with the four-stage synthesizer. With just one filter capacitor [e.g., C1 in its four-stage sibling in Figure 1], the 60-kHz sine wave exhibits a mere 0.14% THD. An eight-stage synthesizer will have 2.613, 1.413, 1.083, 1.000, 1.083, 1.413, and 2.613 normalized values.

A small price to pay for this performance and simplicity is that the clock frequency must be the desired sine wave frequency multiplied by the number of stages multiplied by two. To synthesize the 60-kHz sine wave in four stages, a 480-kHz clock (i.e., 60 x 4 x 2) is needed. Rather than looking for a 480-kHz resonator, I simply used a 4046 phase-locked...
loop (PLL) with a 60-kHz resonator and a divide-by-8 counter.

**SIMPLE YET ROBUST**

I am quite happy with the performance, simplicity, and robustness of the circuit. It shows that even old technology can produce quick and satisfactory results. The synthesizer is only the first step, but it is also necessary for the repeater, which is the end product. I built the modulator and a pulse sequencer for the simulator using an ATtiny85. The time keeping and pulse generation for the repeater is currently performed by an ARM mBed controller. I am considering adding the synthesizing and modulation functions to it as well. At a later date I plan to revisit the topic, discussing the rest of my WWVB inconsistent sync solution.

George Novacek (gnovacek@nexicom.net) is a professional engineer with a degree in Cybernetics and Closed-Loop Control. Now retired, he was most recently president of a multinational manufacturer for embedded control systems for aerospace applications. George wrote 26 feature articles for Circuit Cellar between 1999 and 2004.

**RESOURCES**


**SOURCES**

- ATtiny85 Microcontroller
  Atmel Corp. | www.atmel.com
- Loopstick antenna and resonator
  Digi-Key Corp. | www.digikey.com
- AFET Loopstick antenna
  HKW-Elektronik | www.hkw-elektronik.de

---

**$51 PCBS**

**FREE Layout Software!**

**FREE Schematic Software!**

**01** DOWNLOAD our free CAD software
**02** DESIGN your two or four layer PC board
**03** SEND us your design with just a click
**04** RECEIVE top quality boards in just days

expresspcb.com
The TROBOT
A Miniature Articulated Robot

The TROBOT is a compact six-axis robot powered by RC-style servo motors. An MCU acts as a servo controller interface between the robot and a PC running robot programming software.

The TROBOT is a miniature six-axis articulated robot driven by small RC-style servo motors [see Photo 1]. It is modeled after a much larger ABB Robotics Products industrial robot, the IRB 6640, which weighs in at about 3,000 lbs, can lift up to 500 lbs, and can move at speeds up to 23' per second. At about one-ninth the size of the IRB 6640, my TROBOT would be squashed in the blink of an eye if the two were to meet unexpectedly.

Like most projects, this one involved various stages of development. The second version of the design, TROBOT 2.0, featured a WIZnet W7100 Internet MCU [see Photo 1a]. The third version, TROBOT 3.0, was built with a Texas Instruments [Luminary Micro] LM3S9B96 microcontroller [see Photo 1b]. I'll focus on the latter in this article. A useful schematic is posted on the Circuit Cellar FTP site.

DESIGN SIMULATION
As an experienced robotic controls engineer, I've used ABB's RobotStudio software to develop large industrial robot applications in the automotive, forging, die-casting, and foundry industries. As an electronics tinkerer, I've been using small RC servo motors for projects since I was a kid. Recently, I gained access to a laser engraver and cutting machine to further support my acrylic and plastics fabricating projects. The TROBOT is the end result of combining all my interests.