

The Tuna Tin Transmitter Revisited

This new take on a timeless design adds firmware for 60-meter operation.

Bob Fontana, AK3Y

In the May 1976 issue of *QST*, Doug DeMaw's, W1CER (better known as W1FB, SK), article "Build a Tuna-Tin 2" introduced a two-transistor QRPp transmitter that would influence generations of amateur experimenters. It embodied DeMaw's belief that careful design and thoughtful operating practice mattered far more than output power or component count.

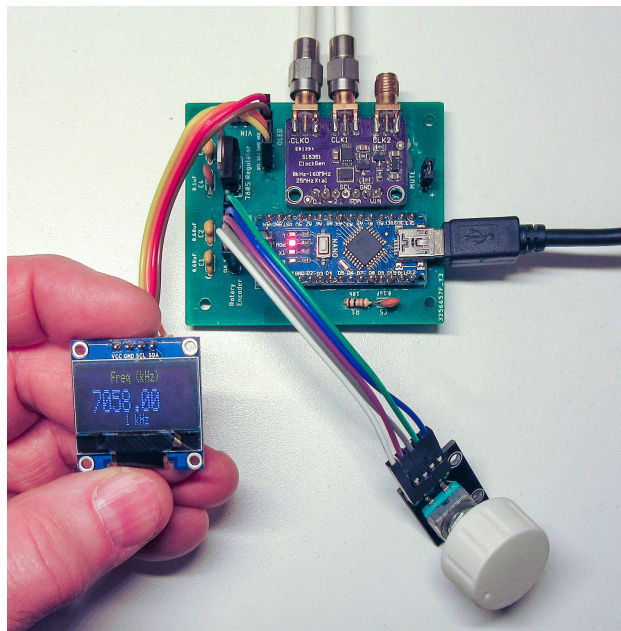
Nearly 25 years later, Ed Hare, W1RFI (SK), revisited the concept in the March 2000 issue. His updated version in "The Tuna Tin 2 Today" demonstrated how modern advances could be incorporated without sacrificing simplicity or accessibility.

I adapted the design further in my article "The Tuna Tin 'S' — A Bare-Bones Synthesized QRPp Transmitter" in the December 2020 issue. Remaining faithful to the small size and low cost of its predecessors, the Tuna Tin "S" replaced crystal control with a Silicon Labs Si5351 frequency synthesizer. This addition enabled an integral variable frequency oscillator, a digital frequency display, and a higher-power MOSFET final amplifier, showing that modern frequency synthesis could be integrated into a minimalist transmitter while maintaining spectral cleanliness. My next take on the design was "Modifications for the Tuna Tin 'S' QRPp Transmitter" in the September 2022 issue.

Since that publication, operating practices and supporting tools have evolved. The FCC's authorization of contiguous amateur operation on 60 meters has increased the practical value of flexible frequency generation. Improvements in open-source Si5351 software libraries have also made synthesized designs easier to implement, more accurate, and easier to maintain. Together, these developments motivate a fresh look at the Tuna Tin "S" synthesizer and the enhancements described in this article.

I present an updated Si5351 synthesizer implementation using the original Tuna Tin "S" hardware platform, but with an entirely new firmware architecture. While the RF hardware remains unchanged, the reworked firmware improves usability, accuracy, and operational flexibility. Key enhancements include:

- A simplified and more transparent frequency-generation framework using the Etherkit Si5351 Arduino library



Assembled Si5351 synthesizer showing the microcontroller, clock generator module, OLED display, and rotary encoder.

- A built-in 10 MHz calibration helper mode that allows precise crystal correction to be established and stored in electrically erasable programmable read-only memory (EEPROM)
- Full firmware support for traditional channelized operation and the newly authorized contiguous 60-meter segment
- Improved tuning ergonomics, including encoder acceleration for rapid frequency changes and per-band frequency memory
- More robust EEPROM management that minimizes unnecessary write cycles while preserving operating parameters
- Support for simultaneous dual-output operation, allowing the Si5351 to generate a transmit frequency and an offset local oscillator for receiver mixer applications

Hardware Overview

The synthesizer hardware is identical to that described in my December 2020 *QST* article. It is based on a Silicon Labs Si5351 clock generator module driven by a small microcontroller, with output buffering suitable

for HF operation. A rotary encoder and a small OLED display provide a compact user interface.

Because the hardware design, schematic, and printed circuit board (PCB) have been previously published, they will not be repeated here. The original schematic and Gerber files are included again at www.arrl.org/qst-in-depth. Consult the 2020 article for construction details. The lead photo shows the assembled synthesizer, including the Si5351 module, microcontroller board, OLED display, and rotary encoder.

Output Waveform and Filtering Considerations

The Si5351 produces a CMOS square-wave output rather than a sinusoidal signal. As a result, the synthesizer output is rich in odd harmonics, extending well beyond the fundamental frequency. The Si5351 module used in this design does not include onboard harmonic filtering, and there is no low-pass filter incorporated on the synthesizer PCB. For transmitter applications, the user must therefore provide an external low-pass filter appropriate for the operating band to ensure spectral compliance. In the original Tuna Tin “S” transmitter, this filtering was implemented as part of the RF output network, and it remains essential for using the updated synthesizer firmware described here.

One practical advantage of the square-wave output is that it can directly drive mixer stages or switching circuits without additional buffering or waveform shaping. This makes the Si5351 particularly attractive for minimalist transmitters, direct-conversion architectures, and experimental RF designs where logic-level local-oscillator signals are desirable. The measured output from the synthesizer at the fundamental frequency is typically +10 to +12 dBm, which is more than adequate to drive a double-balanced mixer or function as an exciter for a following MOSFET amplifier.

Firmware Architecture and Frequency Generation

The most significant changes in the updated Tuna Tin “S” design occur in firmware. In addition to generating the primary transmit frequency, it supports simultaneous dual-output operation. A second Si5351 output may be configured as a fixed-frequency local oscillator offset by a predefined intermediate frequency. This capability extends the synthesizer’s usefulness beyond a simple exciter, making it suitable for superheterodyne and direct-conversion receiver architectures as well.

In the original Tuna Tin “S,” the firmware exercised direct, register-level control of the Si5351 device. While effective, that approach required explicit management of phased-locked loop (PLL) parameters, multi-synth dividers, and fractional frequency calculations, resulting in increased code complexity and reduced readability.

In the updated design, frequency generation is handled using the Etherkit Si5351 Arduino library developed by Jason Milldrum, NT7S. This widely adopted open-source library abstracts the low-level details of PLL and multisynth configuration while maintaining precise control over output frequency and drive strength. By leveraging this library, the firmware:

- Generates HF output frequencies with fewer lines of code
- Reduces the likelihood of configuration and arithmetic errors
- Improves code readability and long-term maintainability

The library internally manages fractional-N synthesis and PLL selection, allowing the application firmware to focus on higher-level functions such as user interaction, band limits, calibration, and operating modes, rather than on device-specific register manipulation.

User Interface and Basic Operation

Frequency tuning is accomplished using a rotary encoder. The current operating frequency and tuning step size are displayed on the OLED (see Figure 1).

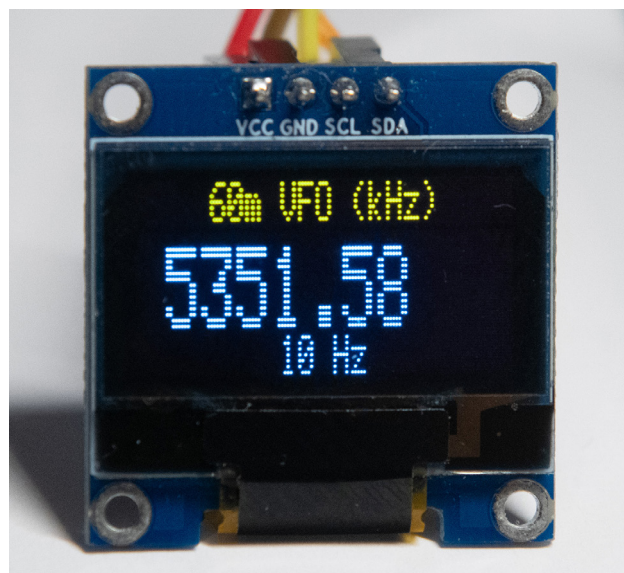


Figure 1 — OLED display during normal operation, showing frequency and tuning step size.



Figure 2 — Calibration mode display during 10 MHz reference adjustment.

A single short press of the encoder switch cycles through available tuning step sizes, allowing rapid band navigation and fine resolution for CW or digital operation. A longer press changes bands and automatically restores the previously used frequency within the selected band.

In normal operation, the synthesizer's primary RF output is provided on Si5351 output port CLK0, which is intended to drive the transmitter exciter. A simple hardware jumper selects whether this output is active.

With the jumper installed, the unit operates as a transmit frequency source, and CLK0 is enabled during transmit operation under firmware control. When the jumper is removed, the firmware disables the transmit output and enables the second Si5351 output (CLK1); this generates a fixed-frequency local oscillator signal offset from the selected operating frequency by a predefined intermediate frequency. The arrangement allows the same synthesizer to function either as a compact low-power exciter or as a receiver local oscillator source without requiring any changes to the user interface or operating controls.

Calibration Mode and Operation

Low-cost Si5351 modules typically exhibit reference-crystal frequency errors on the order of tens of parts per million, which can result in HF output errors of several hundred Hz if left uncorrected.

The built-in calibration routine compensates for this error entirely in software, eliminating the need for hardware trimming. During calibration, the measured differ-

ence between the synthesizer output and an external 10 MHz reference is converted into a correction factor that is applied to all frequency calculations.

Because the Si5351 output frequency scales linearly with its reference oscillator, a single calibration point is sufficient to correct the entire HF range. Normal temperature variations introduce only small residual drift, and recalibration is typically unnecessary unless the operating environment changes significantly. Accurate calibration is especially important when operating near band edges, including those of the contiguous 60-meter allocation.

To enter calibration mode (see Figure 2), press the encoder switch during power-up. The synthesizer outputs a nominal 10.000000 MHz calibration signal while in this mode. Short presses adjust the calibration rate, allowing both coarse and fine correction when comparing the output against an external frequency reference. A long press stores the current calibration value in non-volatile memory and exits calibration mode, which turns the synthesizer back to normal operation.

Once stored, the calibration factor is automatically applied to all subsequent frequency calculations and retained across power cycles.

Support for 60 Meters

When operating on 60 meters, tuning is constrained by firmware to prevent accidental out-of-band transmissions while still allowing for smooth frequency adjustment within the authorized segment.

The synthesizer can output any of the original five discrete frequencies permitted under 47 CFR §97.303(h)(1) (channelized mode). It can also permit output within the newly authorized 15 kHz continuous segment from 5351.5 to 5366.5 kHz.

Spectral Performance Measurements

Spectral purity remains a critical requirement for any synthesized transmitter. To verify performance, I examined the synthesizer output using a laboratory spectrum analyzer across several HF bands.

Figure 3 shows representative spectra at 7.026 (A) and 10 (B) MHz. In both cases, the fundamental output is clean and well defined, with spurious products significantly below the carrier. The noise floor is dominated by the measurement system rather than the synthesizer itself.

Figure 4 shows a swept measurement across a portion of the 60-meter band. It demonstrates consistent

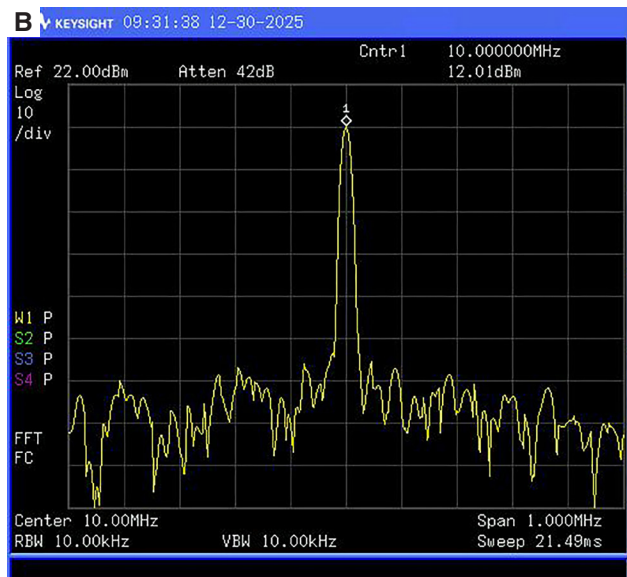
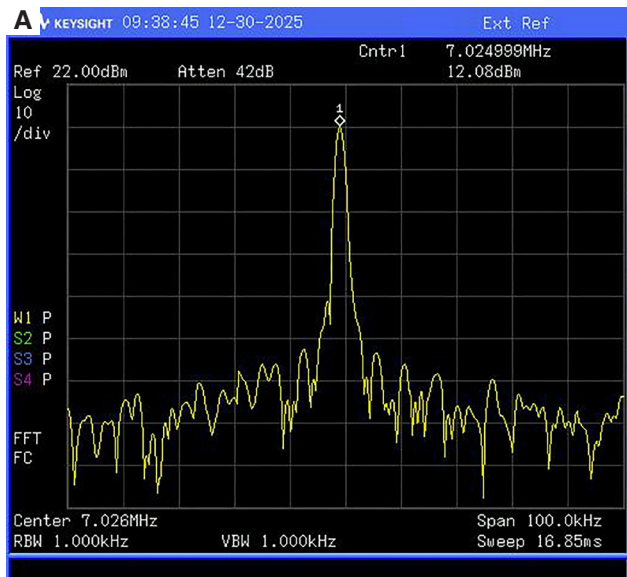


Figure 3 — Spectrum analyzer plots at 7.026 (A) and 10 (B) MHz showing low spurious content.

output amplitude and spectral cleanliness across the authorized range.

The Improvements Summarized

By retaining the original hardware while modernizing the firmware, this updated Si5351 synthesizer demonstrates the usefulness of the Si5351 for amateur experimentation. Using a mature open-source library simplifies development while maintaining excellent frequency accuracy and spectral purity.

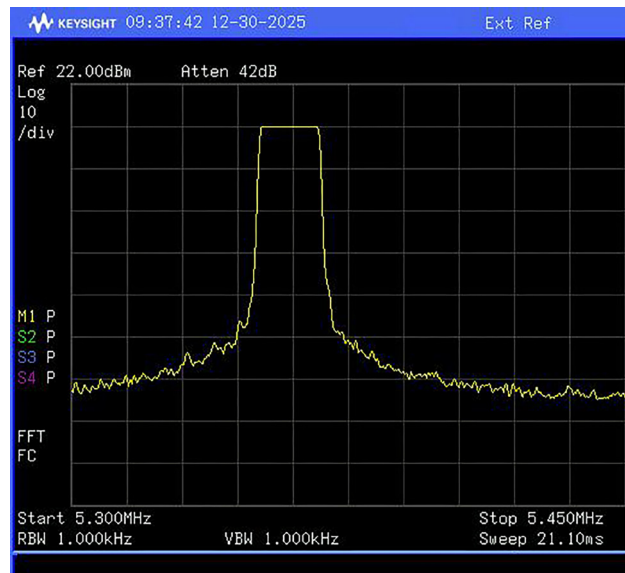


Figure 4 — Swept spectral response across the new FCC allocation in the 60-meter band.

The addition of a built-in calibration routine allows the synthesizer to achieve frequency accuracy suitable for modern digital modes, precision CW operation, and regulatory compliance on bands such as 60 meters. Firmware-enforced band limits further enhance operational safety.

Through simplified firmware, integrated calibration, and support for the FCC's contiguous 60-meter allocation, the design offers improved usability without increased hardware complexity.

See QST in Depth for More!

Visit www.arrrl.org/qst-in-depth for the following supplementary materials and updates:

- ✓ The device's Gerber files and schematic

All photos provided by the author.

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