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A Frequency Counter for the Experimenter

Here is a classic workbench general purpose instrument, with better than 26 mVrms sensitivity from 30 Hz to 2.2 GHz.

Frequency counters are considered indispensable tools for experimenters and basic models can be found on the market for reasonable prices nowadays. Nevertheless, besides basic features like good sensitivity and variable gate times, I wanted something more, like the possibility of synchronizing to external high-stability time bases. (I have an old HP 10811-60164 time base and one of these days I will gather enough courage to build a GPS receiver and lock this unit to the 1 part per second cesium-based reference signal.) I also wanted a counter that could do all the boring math when connected to the VFOs of the QRP rigs I have been building for years, independently of the mixing strategy. It should also measure lower frequencies, down to audio range. As I didn't find such an instrument having a reasonable price, I started designing my own.

The final result was a two-channel counter, the first channel ranging from 30 Hz to 55 MHz, with high impedance, and the second channel from 55 MHz to 2.8 GHz, with a 50 Ω impedance. Four gate times were included: 0.01, 0.1, 1 and 10 seconds. It can measure period too, up to 25 kHz, and display the result as time or frequency, at your choice. We can also introduce an offset — there are pre-defined offset frequencies you can choose (based on the most common IFs found on homebrew and basic commercial rigs) or you can just input the frequency of your choice and it will be memorized. Although the main objective was sinusoidal signals, it will work with other waveforms, like square or triangular waves. A low-battery alarm was also included.

Construction

Both channels must be very well shielded.

The frequency counter in this project is connected to a commercial RF generator.

Photo A shows the front end enclosure that I built. Another important thing is to provide a path as close as 50 Ω as possible from the Channel B connector (the high frequency channel) to the prescaler (LMX2326). I used a 0.1 inch trace on the circuit side. FR4 (fiber glass) material is a good choice for the board (although I have used phenolic material), with a ground plane on one side and the circuit on the other. Use surface mount devices (SMD) for both channels.

The original unit has four printed circuit boards: front end, power supply, time base and control board, and all boards were assembled using 0805 surface mount technology (SMT) components, except for the processor and some components here and there. I suggest a shielded enclosure for the unit, to reduce electromagnetic interference (EMI) problems. The main box was built using one sided phenolic boards. The lead photo shows the assembled unit.

It would be wise to orient the external sync connector to the outside — a quick connection type would be great, like a subminiature B (SMB) connector. I have used ordinary (though good quality) BNC connectors for the channel inputs.

Circuitry

Figure 1 shows the schematic diagram

of the front end circuit board. On the low frequency channel (Channel A), the FET provides high input impedance. It is followed by two amplifiers and a Schmitt trigger inverter that "digitizes" the signal. The high frequency channel (Channel B) input has a 3 dB pad that helps to define the 50 Ω path between the connector and the monolithic amplifier. The LMX2326 is a low power phase locked loop (PLL), but only its prescaler is used here. Channel A has an overall sensitivity of about 25 mV RMS from 30 Hz to 55 MHz, (from 0.2 Hz for square waves). Channel B has roughly the same sensitivity, from 55 MHz to 2.2 GHz. Above 2.2 GHz, the sensitivity is degraded to about 150 mV RMS at 2.8 GHz. Careful layout for the Channel B input could probably improve this behavior. The power supply of the channel not selected is switched off, to avoid interaction and to minimize power consumption. Maximum levels are 50 V peak for Channel A and +16 dBm for Channel B.

The power supply (see Figure 2) was provided with a protection circuit at the power
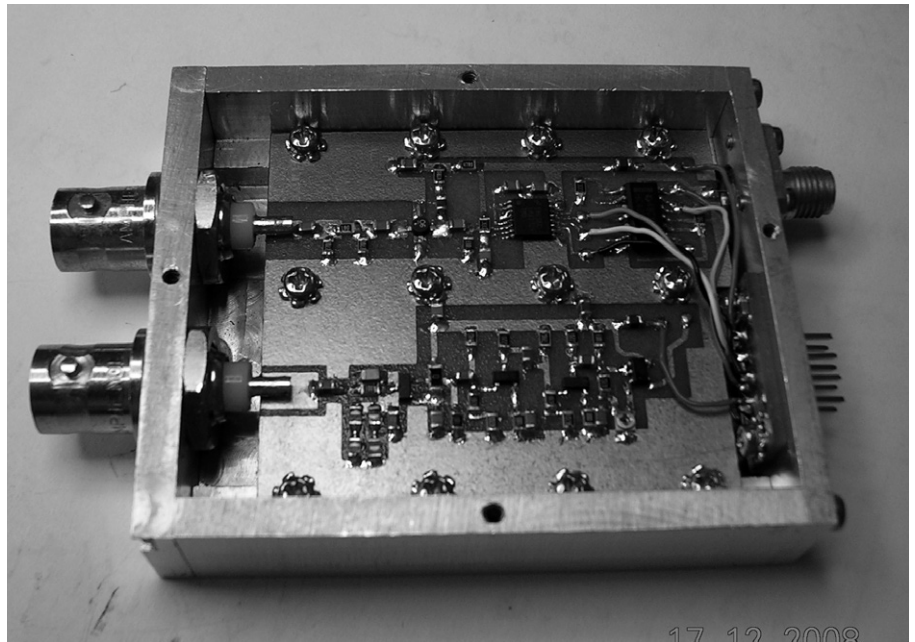

Photo A — It is best to build the counter front end circuitry into a shielded enclosure.
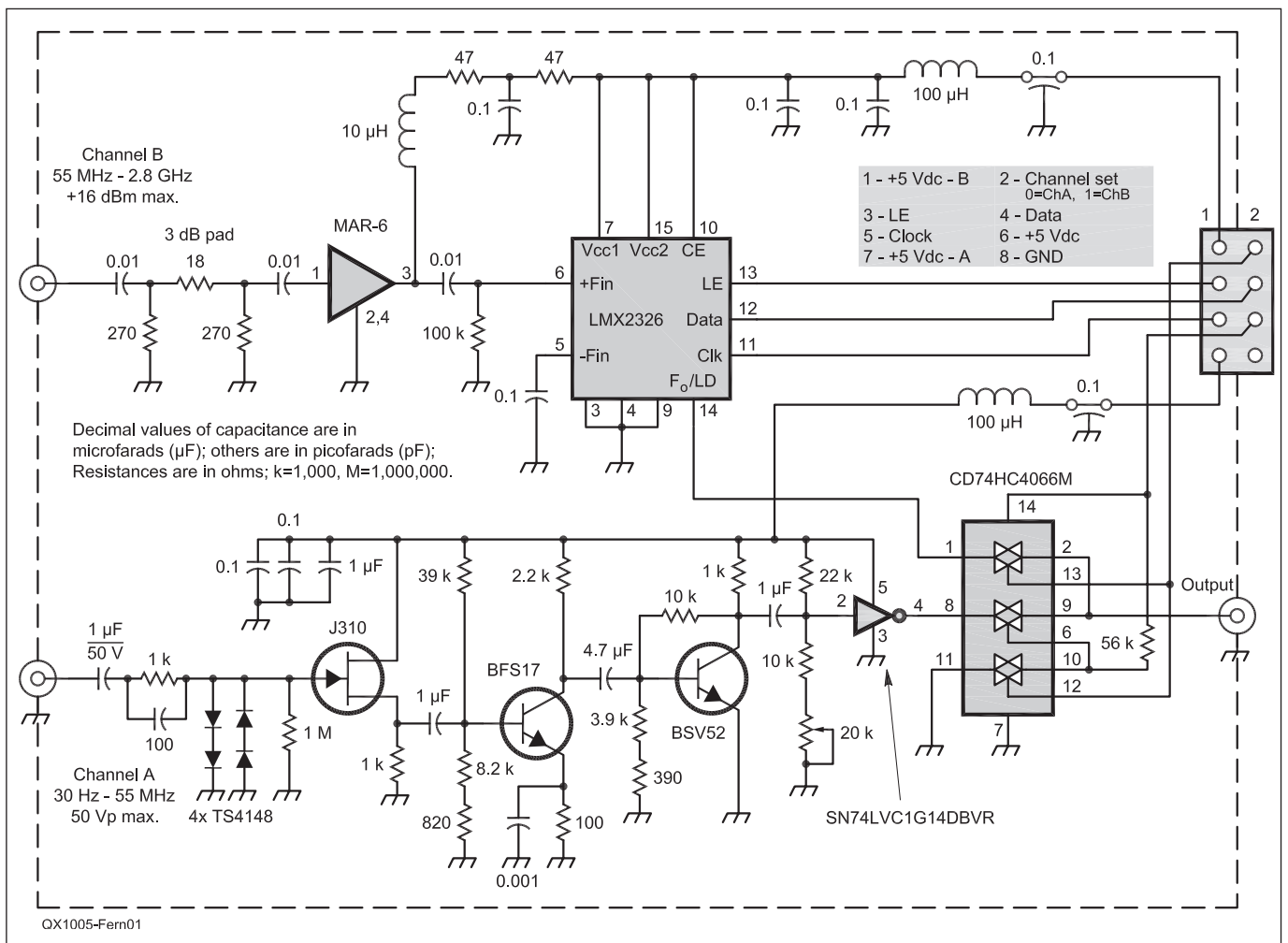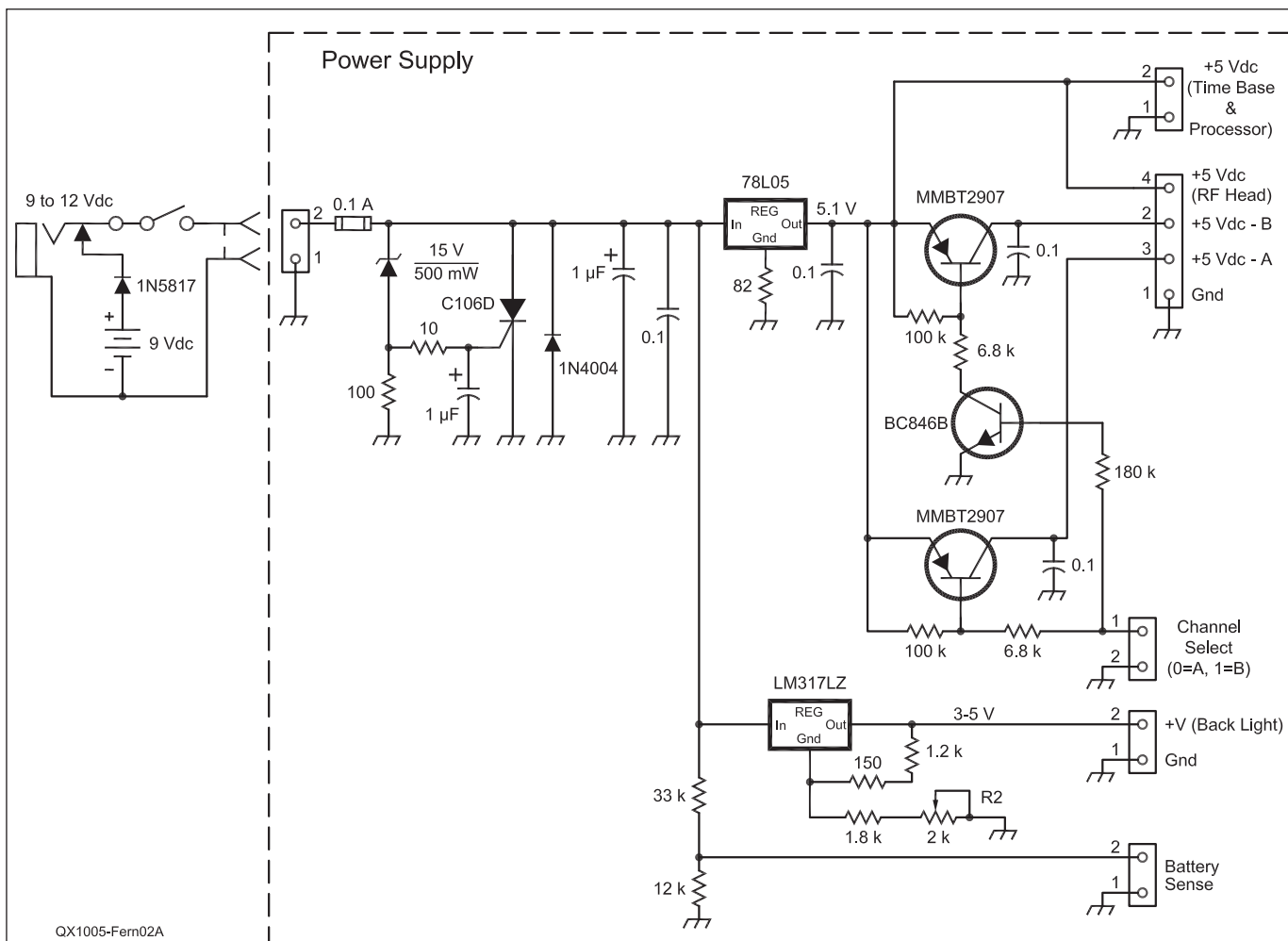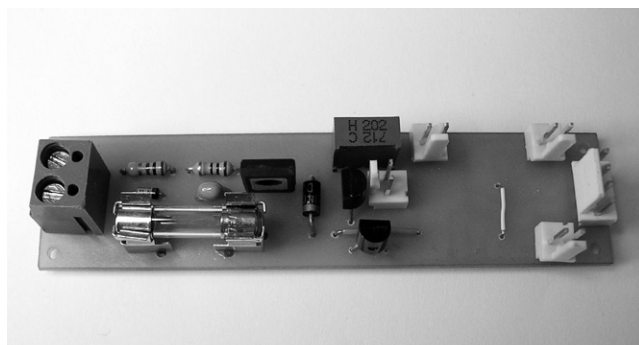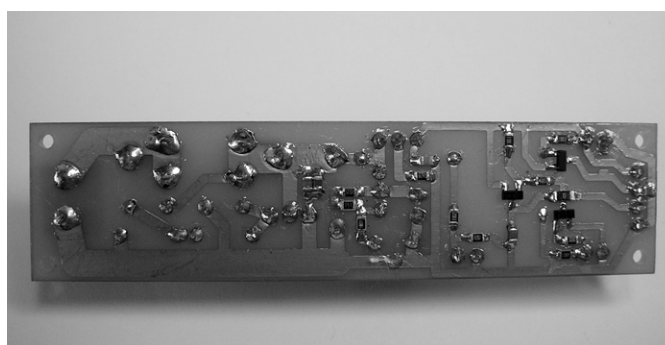

Figure 1 — Here is the schematic diagram of the counter front end circuitry.

Figure 2 — The schematic diagram at Part A shows the counter power supply. Part B shows the top of the supply circuit board and Part C shows the bottom of the board, with circuit traces and SMT components.

input (9-12 V dc) that can be omitted if you have a tidy workbench and well behaved friends. The fuse will blow if you have an internal short circuit, if the supply leads are inverted or in the case of an overvoltage (>15 V dc). The power supply module generates 5 V dc for general use, switchable 5 V dc for the front end channels and an adjustable voltage for the display back light.

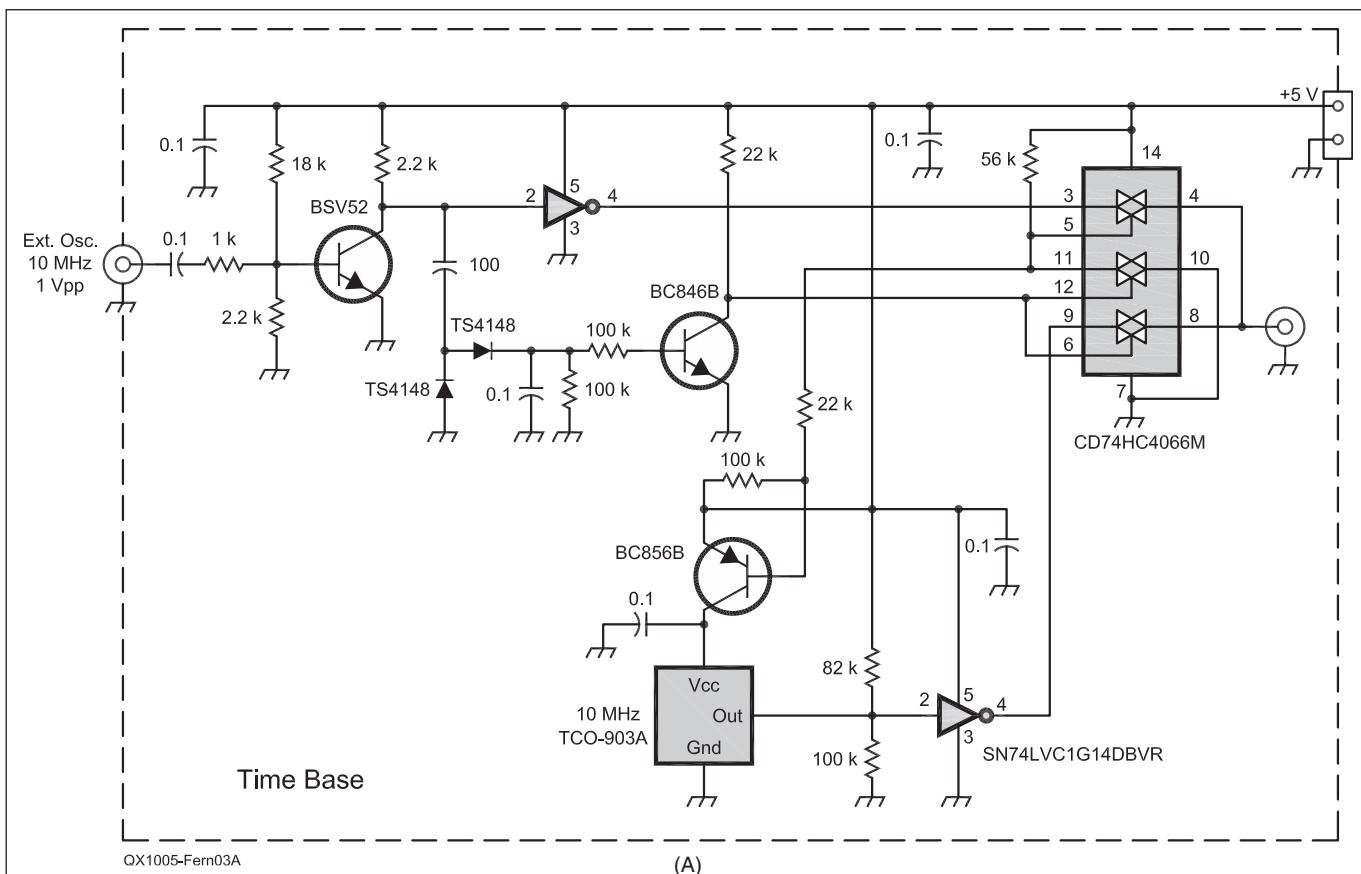Figure 3 shows the schematic diagram of the internal time base, along with photos of the top and bottom of my circuit board. In the original counter, I used a commercial adjustable oscillator, disassembled from a piece of old NEC equipment. I suggest the two-transistor circuit of Figure 5 for the internal time base, noting that the capacitors that are part of the oscillator are all NPØ, including the trimmer — SMT fixed capacitors would be fine. I have tested this circuit with an ordinary crystal, and the circuit worked very well. It would be a very good idea to enclose the circuit with a small shielding box. When you connect an external time base signal with 1 Vpp, the internal reference is automatically switched off.
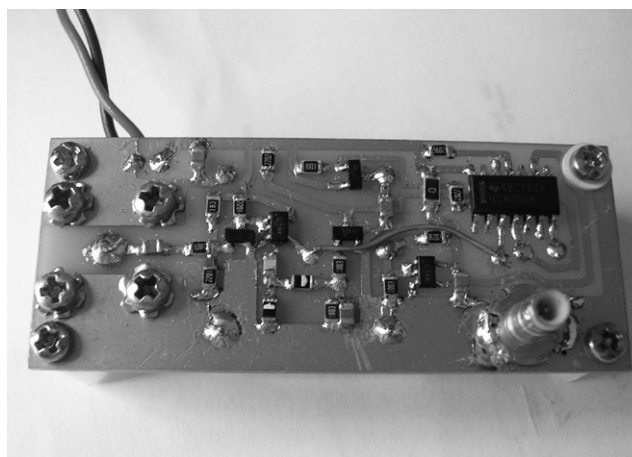
The PIC16F876A processor is the heart of the counter and it also controls the display, which requires much less power for its blue back light than the older green ones.

Adjustments

There are only four adjustments in the counter. First of all, adjust the trimpot on the processor board for the best display contrast.

(A)

(B)

(C)

Figure 3 — Part A is the time base schematic diagram for the circuit I used. Part B shows the top of my circuit board, with the commercial 10 MHz module. Part C shows the bottom of my circuit board, with the circuit traces and SMT components.
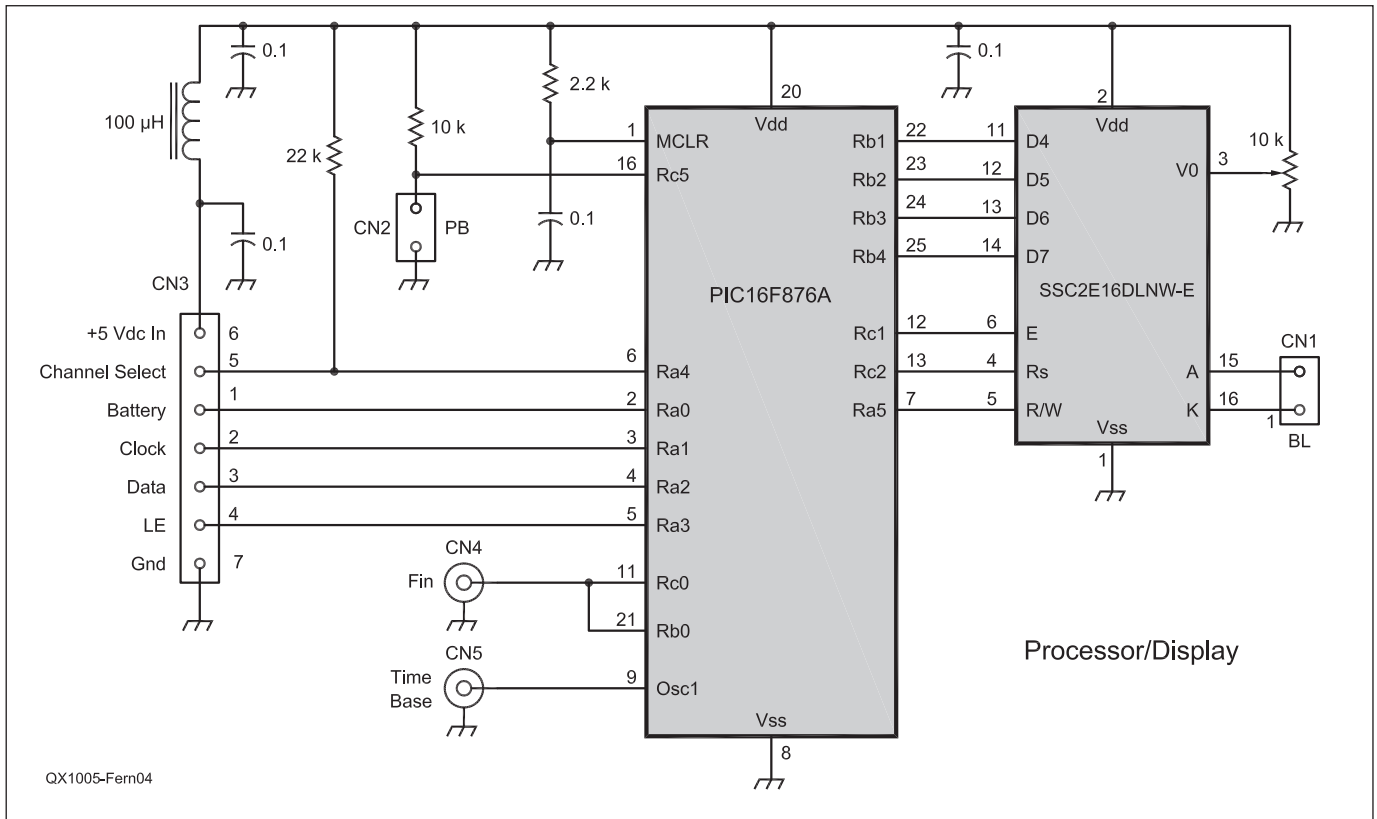
Figure 4 — The PIC 16F876A controller, shown in this schematic diagram, is the heart of the counter.

Now connect a 25 mV RMS, 50 MHz signal to Channel A and adjust the trimpot at the input of the inverter until this frequency (or close) is steadily shown on the display. Increase the frequency up to 55 MHz, always tweaking this trimpot.

Now connect a reference signal (10 MHz, for instance) to the Channel A input. Adjust the internal time base trimmer until the display shows the exact frequency, down to units of Hz. Note that the precision of this calibration adjustment will depend on the precision of this external reference signal.

Finally adjust the power supply module trimpot for a comfortable display back light — if you intend to use this counter frequently with batteries, it would be wise to adjust to the minimum voltage that will still give good readability.

Software and Operation

Excluding the **ON-OFF** switch, this is a one-button-only instrument — pressing and releasing the **MODE** button will give the SCROLL command, and pressing and holding the button will give the ENTER command. If you are in the main display, scrolling will toggle between Channel A
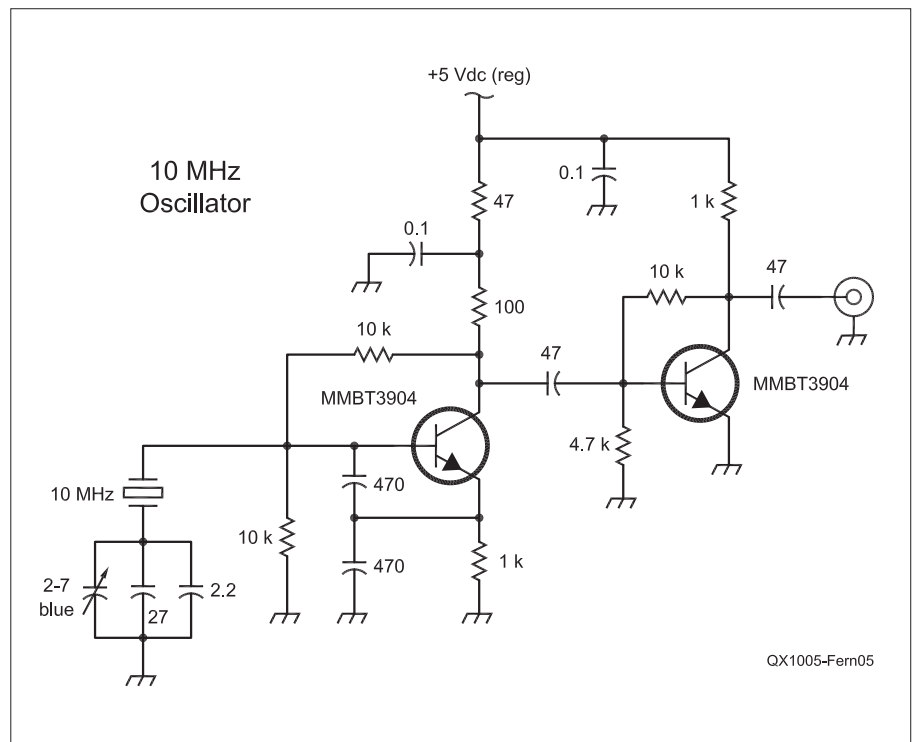

Figure 5 — This 10 MHz reference oscillator can be used as a reference oscillator for the counter.

and B and ENTER will take you to the main menu. The following choices will be shown: gate options, period measurements and offset.

Gate options: Select the gate time — 0.01, 0.1, 1 or 10 seconds. This is the time the gate will be open for the measurement. Faster measurements will give less precision.

Period: When you measure frequency, the gate will be kept open for a defined extension of time and the events will be counted — on the other hand, when you measure period, two subsequent events will respectively open and close the gate, and the time between the events will be measured. For this reason, measuring the period of low frequency signals will lead to more accurate results. You can measure very low frequency signals using this technique, and the result can be shown as frequency or as time. Remember that Frequency = 1 / Period. To leave the Period mode and start the Frequency mode, just choose a gate time.

Offset: Here you can add or subtract a frequency to the signal present at any input. There are some predefined frequencies you can choose, related to the IF channel of simple rigs, or you can use the "Extern" option: just input the offset frequency and choose this option. Example 1: suppose you have a 40 m (7 MHz to 7.1 MHz) CW rig, a 4 MHz IF filter and a 3 to 3.1 MHz VFO. In this case, connect the counter to the VFO and choose plus 4 MHz.

Example 2: Now you have the same band but a 10.7 MHz IF and the VFO ranging from 3.7 to 3.6 MHz. This time choose a –10.7 MHz offset, and everything will be just fine. The software will take care of the negative values and will show the correct frequency of the signal at the antenna.

There are many options you can use to load the hex file into the processor. Some of them (both software and hardware options) have been shared among Internet users. Particularly, I have downloaded the MPLAB IDE software from the Microchip Web site (IDE stands for Integrated Development Environment), because it has interesting tools for the developer and I have a compatible programmer.

A Word of Caution

This counter was designed for amateur use and I have purposely pushed the limits of the processor and prescaler to reach a desired performance. I have tested the circuit with samples I had, analyzing the circuit behavior with frequencies even higher than those stated here and I would expect the same performance for average chips. As a matter of fact, two more prototypes were assembled with other chips, leading to same results. Nevertheless, if you don't want to step into the dark side of the force and/or don't care about the world above 550 MHz, replace the LMX2326 with an LMX2306 (same pinout). The software, in this case, has to be changed and the channel B sensitivity will be around 5 mV RMS, from 25 MHz up. I suggest, in this case, that you replace the original front end pad with a 9 dB one, resulting in an overall sensitivity better than 10 mV RMS. The hex program files for both versions are available for download from the ARRL *QEX* files Web site. (See Note 1.)

Final words

I have been using this counter for over a year, and it is extremely useful, together with other home built equipment I have made. Many concepts used here were derived from good technical literature and research on the Internet, especially concerning component data sheets.[2, 3] The design of this counter was also possible due to good friends: Delson, PY2DME, helped me with measurements above 1 GHz. Eduardo, PY2GNZ, assembled and tested prototypes and Jorge, PY2PVT, made the circuit boards.

During the final stages of preparing this issue of *QEX* for the printer, I discovered that National Semiconductor recently discontinued production of the LMX2306/2316/2326 family. While these chips are still available from some sources, stock will be limited and they may become scarce in the near future. I learned that the Analog Devices ADF4116/4117/4118 family of ICs appear to be equivalent, in terms of specifications, functions, pinouts and packages, but I can't be sure that they will work with the same software, and provide the same performance without assembling a new set of counter boards and testing them. The Analog Devices ICs are available from Digi-Key. I would like to note that last year the LMX family of parts were easy to find at very good prices, but the market is very dynamic, and the manufacturers only want to produce parts for which there is a very large market.

Notes

[1]The author's hex code program file is available for download from the ARRL Web site *QEX* files area. Go to **www.arrl.org/qex files/** and look for the file **5x10_Fernandes.zip**.

[2]Wes Hayward, W7ZOI, Rick Campbell, KK7B, Bob Larkin, W7PUA, *Experimental Methods in RF Design*, ARRL, ARRL Order No. 9239, $49.95. ARRL publications are available from your local ARRL dealer or from the ARRL Bookstore. Telephone toll free in the US: 888-277-5289, or call 860-594-0355, fax 860-594-0303; **www.arrl.org/shop**; **pubsales@arrl.org**.

[3]Bob Okas, W3CD, "The Norcal Frequency Counter – FCC-1," ARRL, *QST*, Sep 2006, pp 28-32.

Rubens R. Fernandes earned a BS in Electrical Engineering in 1970, and worked for about 31 years in the telecommunications industry, in research, design and production. He retired about 5 years ago. He has been a licensed Amateur Radio operator since 1979, and held the call sign PY2QE while living in Brazil. He is a CW enthusiast. He now dedicates his spare time to home brewing small transceivers and test equipment. He has a small workshop that includes mechanical, electrical, software and silk-screening facilities.

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