By Neil Heckt

A PIC-Based Digital Frequency Display

Build this inexpensive, miniature counter for your test bench or as a display for your superhet or direct-conversion HF, VHF, UHF or SHF rig. Adjustable IF offset and prescale compensation make its application to your radio a snap!

The IF offset required for using a frequency counter to display the frequency of superheterodyne receivers and transmitters has always been a problem—that is, until now. The Digital Frequency Display (DFD) is a frequency counter with a difference. The sidebar "DFD Specifications" gives a quick overview of the project.

IF offsets from 0 to 32.7675 MHz (in 500-Hz steps) can be set via two 15-turn trimmer pots. A discrete input determines whether the IF offset adds to or subtracts from the LO count. This discrete input can connect to the band switch of band-imaging receivers to display the correct frequency for both bands. The LO input limit of 30 MHz covers the HF bands. VHF, UHF or SHF operation requires an external prescaler to keep the DFD input lower than 30 MHz. A third, **PRESCALE,** 15-turn pot sets a multiplication factor from 1 to 256. The LO, IF and resultant displayed frequency are all multiplied by the prescale value, to compensate for the division of an external prescaler. This allows the DFD to display up to 8 GHz with an external prescaler.

A fourth input reads an external resistor to select an operating mode for display. The available modes are: blank (no mode), AM, FM, CW, USB, LSB, FSK and FAX. By incorporating appropriate resistors into the mode-switch circuitry, you may be able to control the mode display from the mode switch in your radio.

Counter displays like the DFD are unsuitable for swept-frequency applications such as spectrum analyzers.

Theory of Operation

The brain of the DFD is a PIC16C71 microcontroller. (See Figure 1.) Like all PICs, this one has an externally incrementable counter and an 8-bit internal prescaler. In the DFD, the PIC prescaler is set to 16. A measurement period of 160 ms provides a frequency resolution of 100 Hz and an update rate of about six times per second.

The 16C71 has four channels of 8-bit A/D conversion. Two channels read the **COARSE** and **FINE** controls to provide a 16-bit number that the software multiplies by 500 Hz to obtain the IF offset. The offset then adds to or subtracts from the measured frequency as determined by the **+/–** (RB7) input. A third A/D channel reads an 8 bit value from the **PRESCALE** pot, which is multiplied by the RF (= LO ± IF) value before displaying the result. The fourth A/D channel reads the mode-programming resistor network. Voltage division across an external **MODE** resistor and R5 determines the mode display. (See Table 1.)

The input section is a CD74HC4046 IC. You may wonder what a CMOS PLL is doing in a frequency counter. Refer to Figure 2, and you'll see. The DFD circuit uses only the two circuits in heavy lines. (Pin 5 is tied high to inhibit oscillation.) Phase comparator 1 (PC1) is an **EXCLUSIVE-OR** gate, and as long as pin 3 is tied high or low (zero frequency),

DFD Specifications

LO input: 0 to 30 MHz, 50 mV P-P (–22 dBm) to 5 V P-P (+18 dBm). Zin = 250 kΩ or less.

IF Offset: Two on-board, 15-turn controls (**COARSE** and **FINE**) select offsets from 0 to 32.7675 MHz, in 500 Hz increments (when Prescale = 1).

ZERO: This input disables IF-offset calculations for direct frequency measurements. Ground (0 V) to disable offset, high (5 V) to enable offset calculations.

+/–: This input determines whether IF offset is added or subtracted from the LO count. This can be connected to the bandswitch of band-imaging receivers.

PRESCALE: Set by on-board, 15-turn pot. Compensates display for external prescalers with divide ratios of 1 to 256 (IF Offset, LO frequency and resolutions are multiplied by the Prescale value)

Display: 16-character LCD

Frequency: 6 digit, floating point in kHz, MHz or GHz (100-Hz resolution when Prescale = 1). Updates 6 times per second

Mode: blank, AM, FM, CW, USB, LSB, FSK or FAX, as determined by external resistor (see Table1)

Power requirement: 8 to 18 V, 30 mA, unregulated

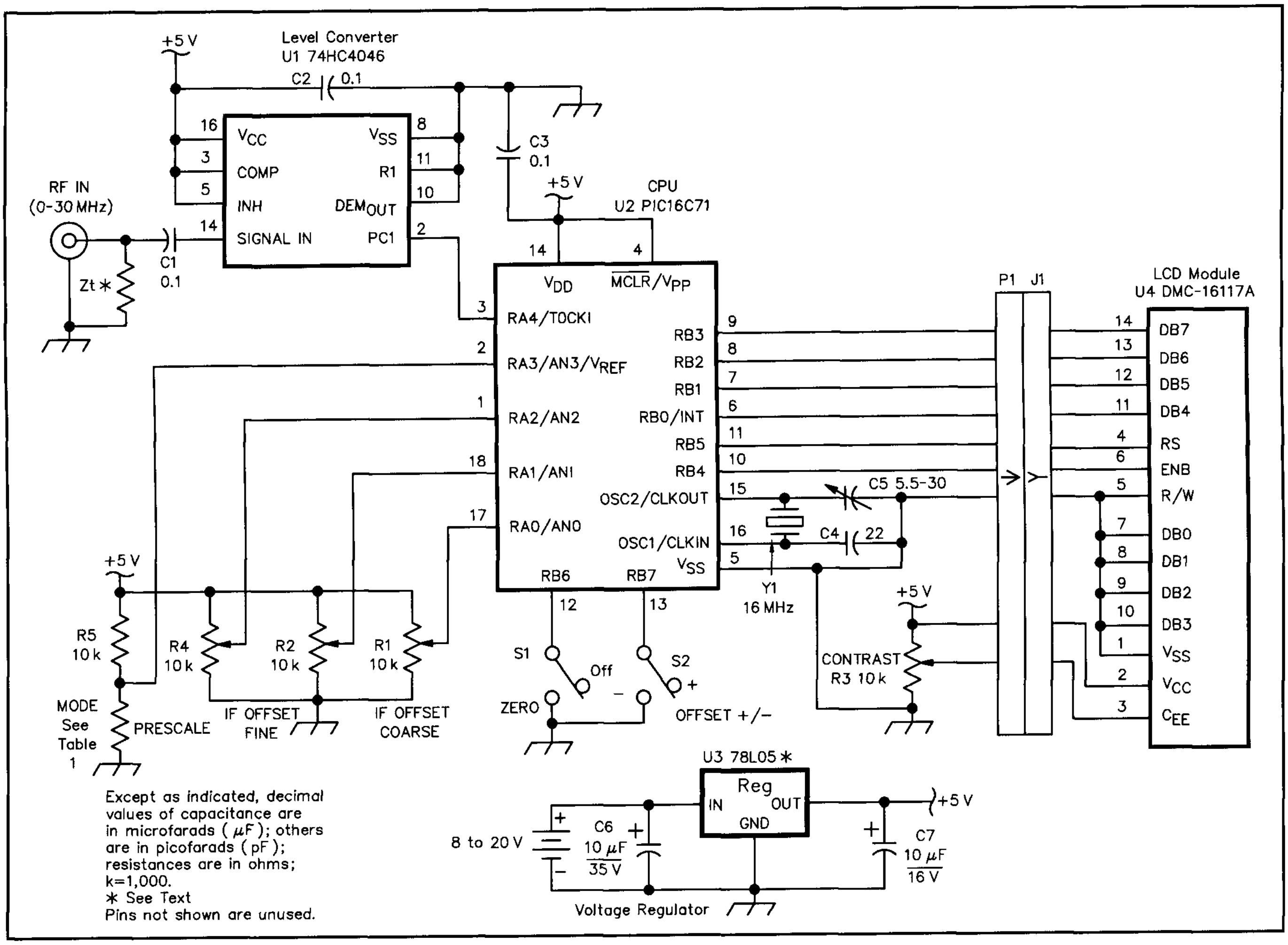

Figure 1—Schematic of the DFD. Unless otherwise specified, use ¼-W, 5%-tolerance carbon-composition or film resistors. Numbers in parentheses are Digi-Key stock numbers. (All parts are available from Almost All Digital Electronics.)[1] Equivalent parts may be substituted for those shown.

C1-C3—0.1 µF
C4—22 pF ceramic
C5—5.5-30 pF 5-mm trimmer capacitor (SG1004)
J1—14-pin, square-post socket (929974-01-36)
P1—14-pin, square-post header (S1022-36)
R1-R4—10-kΩ trimmer pots (3006P-103)
R5—10 kΩ
U1—74HC4046 Radio Shack 276-2913
U2—PIC16C71-20 (PIC16C71-20/P)
U3—78L05 5-V, 100-mA positive voltage regulator (TO-92 case)
U4—Optrex DMC-16117A (10759)
Y1—16 MHz, HC-49 crystal (X176)

[1]Parts and kits are available from Almost All Digital Electronics, 1412 Elm St SE, Auburn, WA 98092; tel 206-351-9316; fax 206-931-1940; e-mail **neil@aade.com;** Web **http://www.aade.com**. Complete kits cost $49.95 + $4 S/H; PC boards, $5 + $1.50 S/H; Programmed U2, $29.95 + $4 S/H. AADE accepts Visa and MasterCard.

output PC1 follows the SIGNAL IN input. This does a fine job of boosting a 50-mV P-P input signal up to 5 V CMOS levels at all frequencies up to 30 MHz. (Not bad with only a bypass cap and a coupling cap as supporting parts.) The 4046 input impedance is 250 kΩ, but you can set the system impedance to any lower value by installing optional resistor Zt on the PC board. The resistance of Zt should equal the desired impedance.

The IF-offset and prescale values are very stable because the A/D conversion is ratiometric. That is, both the A/D converter reference and the trimmer-pot voltages are derived from the same +5 V source. Trimmer capacitor C5 permits adjustment of the PIC clock frequency. Use C5 to calibrate the DFD against a known external standard, such as WWV.

The display is a 16-character intelligent display module that accepts ASCII character codes. It operates in the four-bit (nibble) mode. The software delays between writes to the display rather than using the display "busy" status. This means the display is always in the write mode and the normal R/$\overline{W}$ control line is grounded. Four data lines (D4-D7), and the register select (RS) and enable (ENB) control lines connect to the microcontroller. The rest is a software problem.

From a software point of view, there are two different kinds of 16×1 LCD modules. One is organized as a 16×1 with the 16 characters in contiguous RAM locations. It can be recognized by the two surface-mount ICs on the back. The other is organized as 8×2 with each block of 8 characters in a different area of RAM. It can be recognized by the single surface-mount IC on the back. I programmed the DFD for the display with 8×2 storage.

The counter actually displays the *absolute value* of (LO ± IF). With proper use of the +/− input, the DFD displays the RF frequency correctly regardless of the relationship between LO, IF offset and the RF. This is very helpful for band-imaging receivers.

Table 1
Displayed Mode versus MODE Resistor Value and RA3 Voltage

Mode	*R(kΩ ±5%)*	*V at RA3*
blank	OPEN	5.0
AM	65.0	4.3
FM	27.5	3.7
CW	15.0	3.0
USB	8.8	2.3
LSB	5.0	1.7
FSK	2.5	1.0
FAX	0.0	0.0

If you have a band-imaging receiver for the 17 and 30-meter bands with an IF of 4.0 MHz and an LO of 14.0 to 14.168 MHz, the readout frequencies will be 18.0 to 18.168 MHz (LO + IF) and 10.0 to 10.168 MHz (LO − IF).

If you have a band-imaging receiver for the 80 and 20-meter bands with an IF of 9.0 MHz and an LO of 5.0 to 5.5 MHz, then the readout frequencies will be 14.0 to 14.5 MHz (LO + IF) and 4.0 to 3.5 MHz (LO − IF). In this latter case the frequency tunes backward. Mathematically, LO − IF returns a negative number, however, the DFD will display the correct frequency because it displays the *absolute value* of LO − IF.

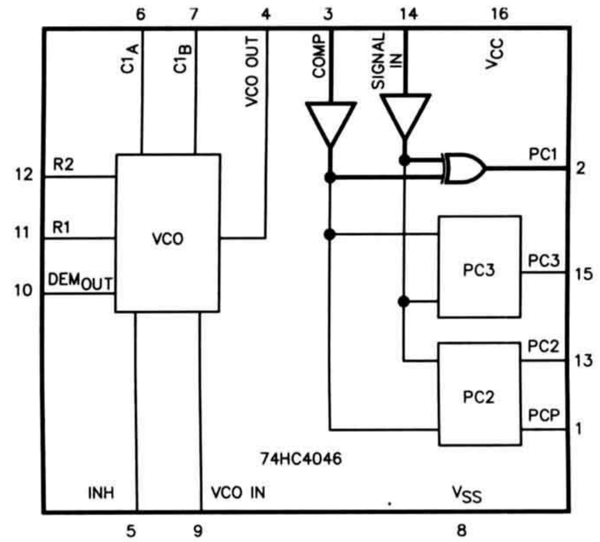

Figure 2—74HC4046 PLL block diagram. Only the two circuits in heavy lines are used in the DFD.

Setting Up the DFD

Adjust the contrast control until the background is just barely visible. Start with the pot at the zero voltage setting (wiper at the ground end, fully counterclockwise). Reduce the contrast to the desired level by turning clockwise.

Superheterodyne Mode (ZERO = +5 V)

When the LO input is shorted, the unit displays the IF offset, which allows it to be easily set. Begin by adjusting the **PRESCALE** pot to the 0-V end (fully ccw). This sets the prescale value to 1. Adjust the **IF Offset** pots until the display shows the desired IF. (If the prescale value is to be greater than 1, adjust the IF offset to IF ÷ prescale.) Finally adjust the **PRESCALE** control to display the actual IF.

For example, if the IF of a UHF device is 100 MHz and the LO input passes through a divide-by-16 prescaler, then, with **PRESCALE** set to 1, adjust for a display of 100 MHz ÷ 16 = 6.2500 MHz then adjust **PRESCALE** to obtain a reading of 100.000 MHz. In this way, both the IF-offset and prescale values will be correctly set. Connect the LO input to a buffered output of your LO and you're up and running.

Direct Conversion, Bench-Top Counter Mode. (ZERO = 0 V)

The IF-offset controls are disabled and the LO input is displayed directly. The **PRESCALE** control still works to display frequency data from an external prescaler.

To adjust the prescale value start with **PRESCALE** set to 1. Use the superheterodyne mode and set DFD for a 1.00000 MHz IF. Then adjust **PRESCALE** until display shows the prescale value. Then ground **ZERO**.

For example, if your prescaler divides by 16, tie **ZERO** high, adjust **PRESCALE** to 1 (0 V, fully ccw), adjust the IF offset to 1.0000 MHz, adjust **PRESCALE** to display 16.0000 MHz then ground **ZERO**.

Operating Tips

For maximum long-term stability, set the IF-offset and **PRESCALE** controls halfway between their transition points.

The DFD includes a regulated battery power supply. You may omit this supply if regulated 5-V power is available.

If you're concerned about battery drain, wire a push-button switch into the power lead. That way the DFD will operate (and draw power) only when you press the button.

Conclusion

The DFD is a versatile, inexpensive frequency counter and display that can be easily adapted to most any radio. Build one and try it with your existing rig or your next project. Even the simplest radios can now sport an accurate frequency display.

Neil was a professional electronics engineer (BSEE) for over 35 years with the Boeing Company of Seattle, Washington. He retired a couple of years ago, and now designs and manufactures kits and software for electronic hobbyists, engineers and radio amateurs as a retirement hobby. Neil's Amateur Radio license (WØNRC) expired in about 1957. He was one of the first SSB operators in those days. He discovered, however, that his interests were in equipment design, rather than operation. Neil has several ham projects under development now, so he plans to get a new license. You can reach Neil at Almost All Digital Electronics (see Note 1).

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