APPENDIX E

FREQUENCY SYNTHESIZER BOARDS

Commentary on frequency synthesizer boards. What's good. What's bad. Etc.

E.1 Hardware

Schematics for various system blocks of the frequency synthesizer are depicted in Figures 36, 37, and 38. The following sections will provide a brief overview of each of the system blocks.

E.1.1 Phase-Locked Loop

The phase-locked loop describes the combination of a voltage-controlled oscillator (VCO), and frequency synthesizer, which contains the phase frequency detector, frequency dividers, and charge pump.

E.1.1.1 Voltage-Controlled Oscillator

The frequency synthesizer board accepts any surface mount voltage-controlled oscillator (VCO) with a 16-pin 0.5 in by 0.5 in footprint provided that the necessary tuning voltage is 0-5 V, and the required power voltage is 5 V. Appropriate VCOs at a myriad of frequency bands are available through companies such as Mini-Circuits and Crystek Microwave.

E.1.1.2 Frequency Synthesizer

The board accepts a range of frequency synthesizer ICs produced by Analog Devices with a 16-lead TSSOP footprint. The board should work with many (though not all) of the frequency synthesizer ICs in the ADF40XX and ADF41XX family. However, the board has only been tested with the following ICs:

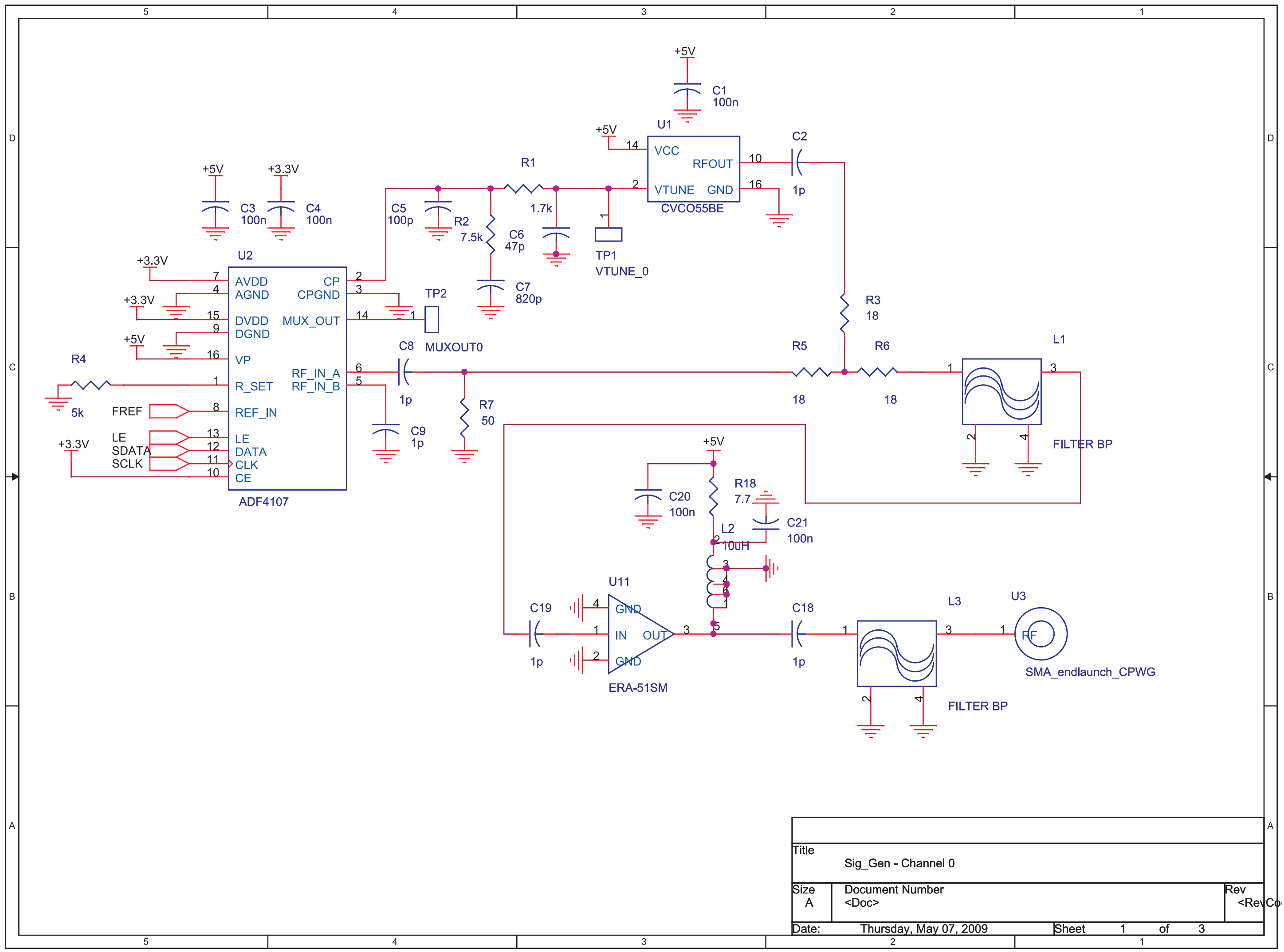

Figure 36: Frequency synthesizer board schematic showing the phase-locked loop, output filters, and amplifier.

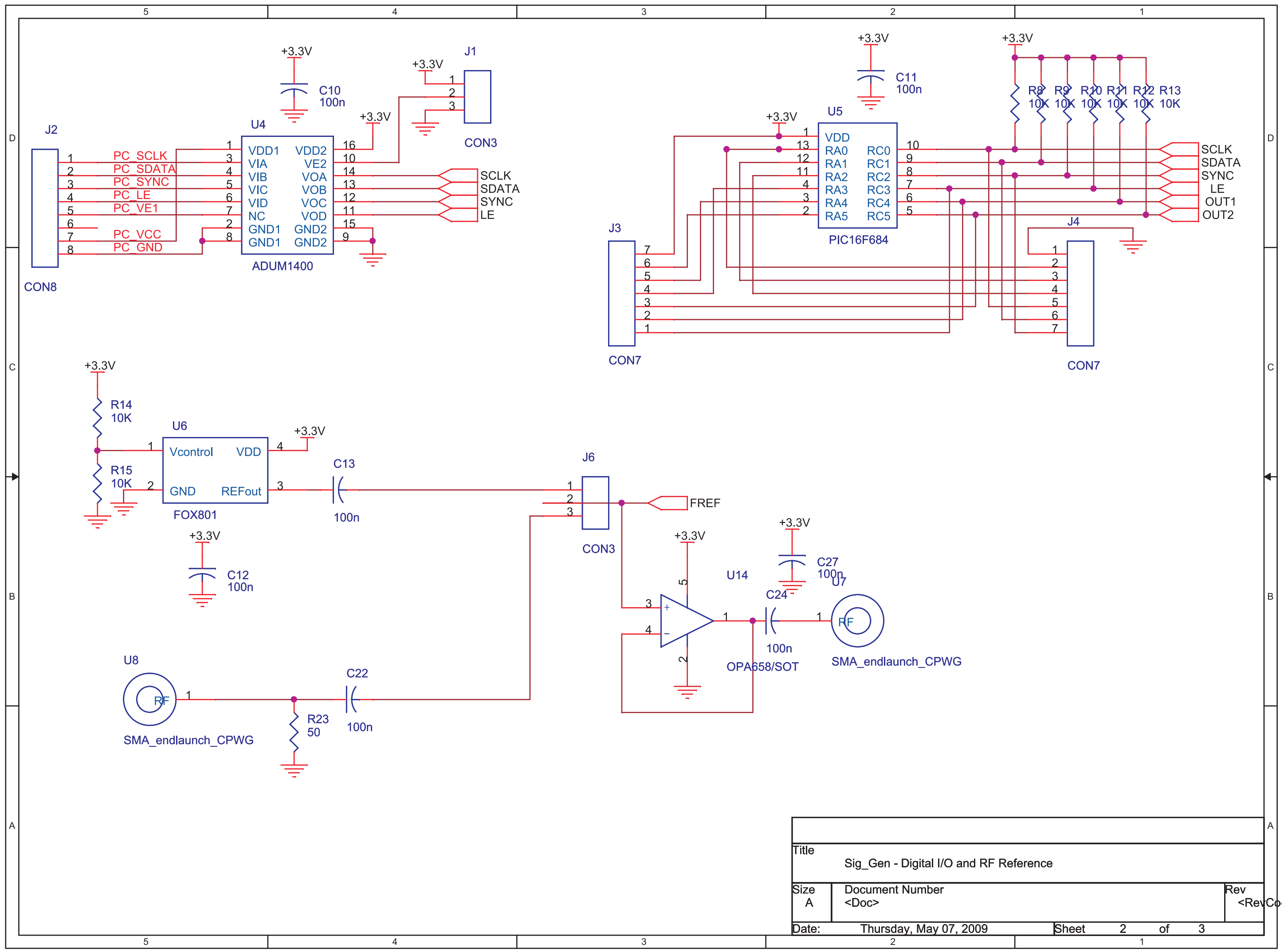

Figure 37: Frequency synthesizer board schematic showing the optoisolator, PIC microcontroller, and 10 MHz reference buffer.

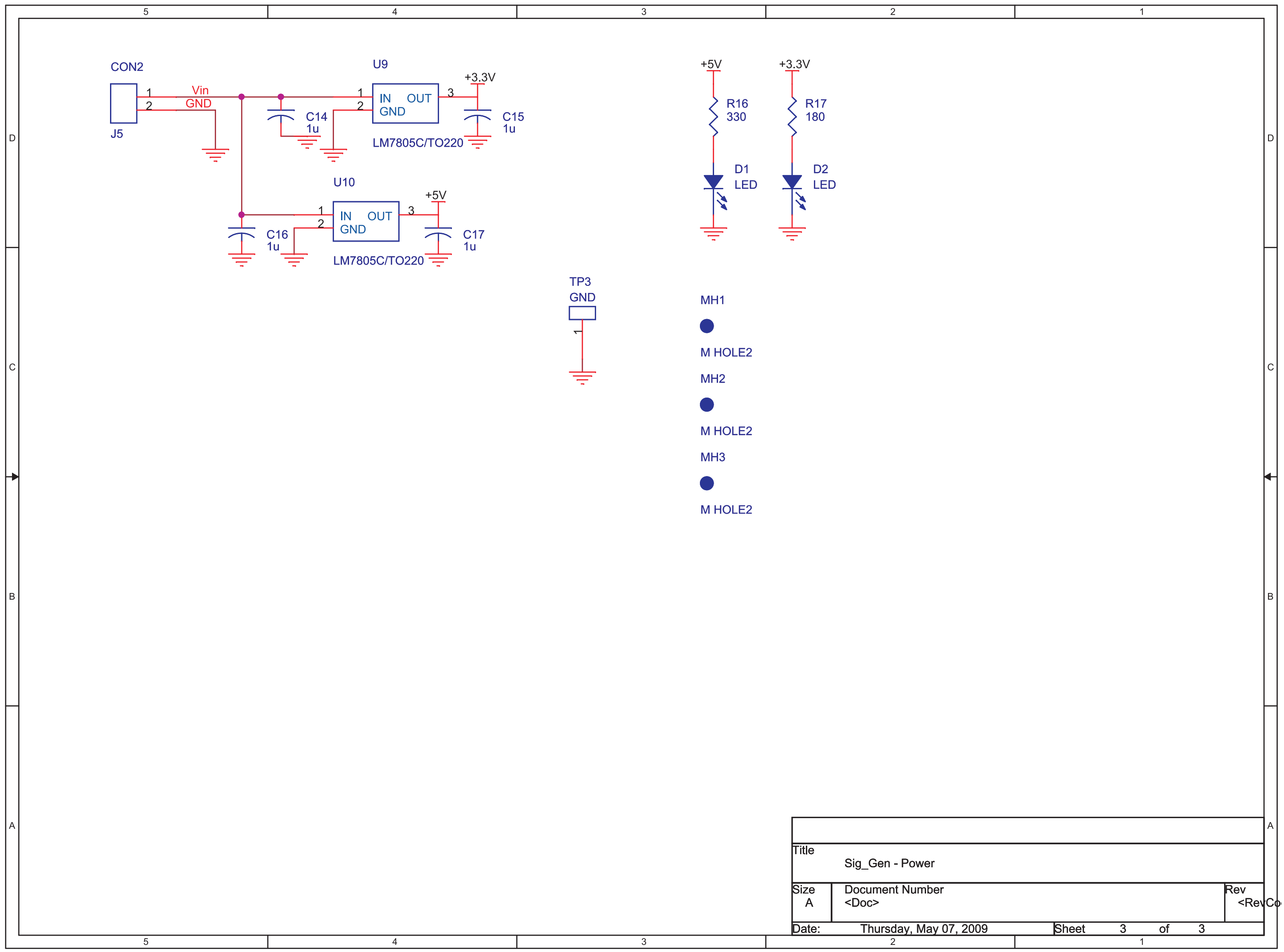

Figure 38: Frequency synthesizer schematic showing the voltage regulators and power rail LEDs.

- ADF4001
- ADF4111
- ADF4107

Generally, it is required that the frequency synthesizer IC be a single "integer-N type" with four 24-bit registers (or latches). The registers will be described as follows:

- Reference counter latch
- N counter latch
- Function latch
- Initialization latch

The reference counter, R, is used to divide down some reference frequency, f_{REF}, which is nominally 10 MHz as is the convention for RF equipment. The N counter latch is used to divide the VCO's output frequency, f_{VCO}, to some more manageable frequency for phase frequency detection. The N counter latch may be composed of either a single 13-bit counter, N, or the combination of a 13-bit counter, B, and a 6-bit counter, A. For the latter case, the first two bits of the *function latch* and *intialization latche* are used to assign a prescalar, P, and N is effectively given by

$$N = PB + A$$

For either case, the VCO frequency will be given by

$$f_{\mathrm{VCO}} = N \frac{f_{\mathrm{REF}}}{R}$$

Thus, by appropriately choosing N (or P, B, and A) and R, one has a great deal of flexibility in setting the VCO's frequency.

When correctly programmed, the frequency synthesizer IC will compare the phase and frequency between f_{VCO}/N and f_{REF}/R and attempt to adjust the tuning voltage of the VCO to correct for any disparity. Differences in phase and/or frequency will produce proportional output signals by the charge pump, which in turn drives the loop filter and sets the VCO's tuning voltage.

E.1.1.3 Loop Filter

The loop filter is a third order low-pass filter as described in CITE, p18. The loop filter features a 70 kHz bandwidth. The charge pump output is filtered by the loop filter to yield a mostly constant tuning voltage for setting the VCO's output frequency and thereby completing the phase-locked loop.

E.1.2 RF Filter

The purpose of the RF filters is to remove any harmonics generated by both the VCO and amplifier. The frequency synthesizer board accepts any of Mini-Circuit's surface mount low-pass filters that use their custom "FV1206" footprint. The filter should have a cut-off just above the desired VCO frequency to ensure that the harmonics are adequately attenuated.

E.1.3 RF Amplifier

The output of the VCO is typically around 0 ± 3 dBm. Following the 6 dB of loss due to the wideband resistive power divider (i.e., the three 18 Ω resistors), the RF signal power is too weak to drive most mixers. Therefore, an amplifier and its associated biasing network are used to boost the frequency synthesizer board's output power. The frequency synthesizer board accepts any of Mini-Circuit's surface mount monolithic gain block amplifiers that use their custom "WW107" footprint. Aside from bandwidth, gain, and 1 dBm compression point, it is important to consider the amplifier's operating voltage, which must be below 5 V. A biasing resistor with an appropriate power rating is used to set the amplifier's biasing current. In Fig. 36, a 7.7 Ω resistor is used to bias a Mini-Circuits ERA-51SM amplifier to 4.5 V and a 65 mA. The inductor used in the biasing network is a Mini-Circuits ADCH-80 RF choke, which prevents the VCO's high frequency output from coupling onto the frequency synthesizer board's 5 V supply.

E.1.4 10 MHz Reference

The lower half of Fig. 36 shows the circuitry used to produce the nominally 10 MHz reference, f_{REF}, for the phase-locked loop. The board allows for either an external frequency reference or an on-board temperature-compensated crystal oscillator (TXCO). For the external frequency reference, the external source should be matched to 50 Ω. For the on-board TCXO, the frequency synthesizer board accepts a Fox Electronics FOX801A TCXO; similar models should work provided the footprint and requires supply voltage are the same. A voltage-divider may be used to fine-tune the TCXO's output frequency. The jumper *J6* may be used to select between the on-board reference and an external reference. It should be noted tha the voltage swing of any reference frequency signal must be within the acceptable limits of both the frequency synthesizer IC and the op amp, which is configured as a voltage-follower to allow for cascading a reference frequency across multiple frequency synthesizer boards.

The capacitors following the on-board frequency reference and external reference input are used to AC-couple the reference signal going into the frequency synthesizer IC. When presented with an AC-coupled reference signal, the frequecy synthesizer IC applies a DC offset at the reference input pin. Thereby, the reference frequency signal seen at the op amp's noninverting input is DC-biased and generally nonnegative. The DC-biased reference frequency signal is buffered by a high-speed op amp before being AC-coupled to the board's reference frequency output. The frequency synthesizer board accepts a 5-pin surface mount op amp using the SOT23-5 footprint such as the

Fairchild FHP3130.

E.1.5 Digital I/O

The board features two digital I/O circuits: an optoisolator and an PIC microcontroller. The optoisolator allows for programming by some external device such as a computer and is useful for testing purposes. For general use, a programmed PIC microcontroller provides all the necessary control over the frequency synthesizer board. The primary function of the digital I/O circuitry shown in the upper half of Fig. 37 is to correctly program the frequency synthesizer IC's four registers so that the phase-locked loop will yield the desired output frequency. The digital I/O is based around a serial peripheral interface (SPI), which requires a clock pin, a data pin, and a latch pin.

E.1.6 Power

As shown in Fig. 38, the board uses a pair of voltage regulators to produce the necessary 5 V and 3.3 V power rails. A pair of LEDs provide feedback concerning the board's power status. Typically, the input voltage provided at jumpber *J5* is already 5 V, so the LM7805 voltage regulator is not used.

E.2 PLL/Microcontroller Programming

Program microcontroller to program PLL upon startup Use MATLAB script to determine necessary PLL registry writes. Enter into header for microcontroller code. Compile and flash.