

AAØZZ Si570 Daughtercard and PIC Software

A Signal Generator for 10 to 157 MHz

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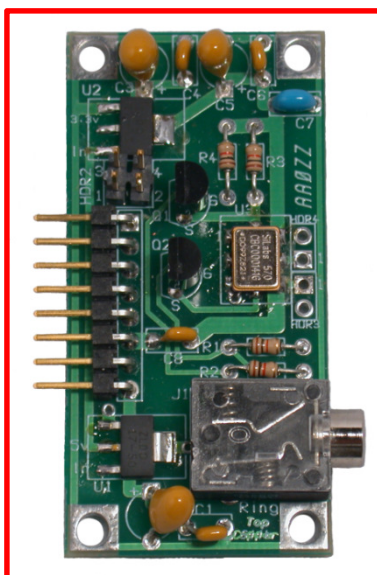


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1 Introduction

This Daughtercard uses the Silicon Labs Si570 DSPLL and software to generate RF signals in the continuous range of 10 to 157 MHz. Since many amateurs use divide-by-four mechanisms in Quadrature Sampling Detectors (QSD) – i.e., “Tayloe” mixers - for their receivers and also in Quadrature Sampling Exciters (QSE) for their transmitters, the Si570 Daughtercard can provide the local oscillator signal for receivers and transmitters which operate on the 80 through 10 meter amateur bands.

2 Hardware Description

The Si570 DSPLL programmable frequency synthesizer is a relatively new technology developed by Silicon Labs. The Si570 offers some advantages over the DDS parts that have been used in applications in the past years. Two advantages are greatly reduced power consumption and the clean output without DDS byproducts (spurs).

Silicon Labs offers several versions of the Si570 with different output options and frequency limits. The version used in the Daughtercard is a CMOS part with a 10.0 MHz default frequency and a 160 MHz maximum frequency. (The upper limit implemented in the PEgen570 application is 157 MHz.) The internal crystal of the Si570 runs at a nominal 114.28 MHz. However, the crystal in any individual part will not oscillate at exactly this nominal frequency. Since the crystal frequency is used in the frequency parameter calculations in the software, the deviation from nominal means that the frequency the Si570 generates will not be accurate. Fortunately Silicon Labs calibrates each individual part and saves the parameters in its nonvolatile memory to cause it to start up at the default frequency (in this case, 10.0 MHz). The software can retrieve the parameters from the nonvolatile memory and calculate the calibrated crystal frequency. This actual crystal frequency can be used in subsequent calculations and the results will be much more accurate than it would be if the nominal crystal frequency was used.

The Daughtercard can be used in a platform of your choice but here are a couple of examples.

2.1 Circuit Description

The schematic is shown in Appendix A.

Since the PIC runs at 5v and the Si570 runs at 3.3v, signal level translation circuitry is necessary. Much of the circuitry on the board exists to do this translation. At first the problem seems trivial to solve but, since it must be bi-directional, it is not quite that easy. At first glance the circuit is quite elegant in its simplicity but when it is looked at closely it is a little more complicated. The design is not original to me but is described in many I2C specifications.

The Daughtercard has two voltage regulators. One converts 12v to 5v and the other converts 5v to 3.3v. Why not just bring 5v from the PIC-EL? Two voltage regulators are used because the PIC-EL header is connected to 12v for the DDS-60 and I didn't want to rewire the PIC-EL for the new Daughtercard.

The Daughtercard has two RF output paths from the Si570 to the headers even though the CMOS version of the Si570 which we use for the Daughtercard only has one output (CLK+ on HDR3). The second RF path (CLK- on HDR4) is there in case a different version of the Si570 is used in the future. The CLK+ signal is also routed to the 8-pin connector (HDR1) so the PIC-EL's RF jack is usable.

Other versions of the Si570 have higher frequency limits but with reduced amplitude output. The spec sheet for the CMOS version says it operates between 10 to 160 MHz but some users report it can be used between 3.5 and 240 MHz. (The upper limit implemented in the PEGen570 application is 157 MHz.)

Header HDR2 is a 2x2 connector block that is not used when the Daughtercard is used in a PIC-EL. However, when the Daughtercard is used in a different platform, two jumpers can be installed in this header block (1 to 2 and 3 to 4) to route the I2C communications through the 8-pin interface connector. This eliminates the need for the external wires from the stereo jack to the platform.

2.2 Daughtercard with PIC-EL Board

One platform for the Daughtercard is the AAØZZ PIC-EL board. (The PIC-EL board is available from Kanga at www.kangaus.com. See details on my web page also.) An AAØZZ Signal Generator sample application for the PIC-EL is available so it is very convenient if you want to experiment with the software.

The Si570 Daughtercard was designed to fit into a socket on the PIC-EL board that was originally designed to accommodate a DDS-30 or DDS-60 Daughtercard from AmQRP. The DDS Daughtercard operates with three control lines. The Si570 Daughtercard is simpler in that it operates with two communications lines. However, the communications scheme used by the S570 is I2C and that means the lines are both bi-directional. This presents a problem for the PIC-EL since two of the three PIC lines that go to the Daughtercard interface are also shared by the LCD and the other line is shared with the programmer. This sharing of pins prevents two-way communications via I2C with these lines. The workaround is to use an external cable to connect the daughtercard to the PIC-EL's paddle jack. The paddle jack connects to different PIC pins and these pins are only shared with PIC-EL Pushbuttons 2 and 3. These two pushbuttons cannot be used when operating the Si570 daughtercard but otherwise the lines work well for I2C communications.

2.3 Daughtercard In Stand-alone Board

To be supplied

3 Si570 Daughtercard Assembly

3.1 Parts Identification

The builder should first identify all the parts in the kit. The parts are listed and described in Appendix B. Every effort is made to include all parts in the kit; however, mistakes do happen. If you are missing a part, notify Bill Kelsey at Kanga and he will send the missing parts to you. It may be faster to get common components from your own "junk box" or at your local Radio Shack store.

3.2 Assembly

The silk-screen part names on the board will be your guide. The order in which you place the parts is not critical but I would suggest that you install the MOSFETs last for static-protection reasons.

Here is a possible assembly order that works well if you have a PIC-EL board.

1. Install the two voltage regulators, U1 and U2. Be sure you distinguish them properly and install them in the correct locations!
2. Install the resistors and the capacitors.
3. Install the header connectors HDR1 and HDR2.
4. Test the voltages coming out of the voltage regulators.

- a) Plug into PIC-EL board and power up.
- b) Use a Volt meter to check:
 - 12v coming into HDR1 pin 8.
 - 5v out of U1. Check at point where regulator connects to C3.
 - 3.3v out of U2. Check at point where regulator connects to C5.
 - IF ANY OF THESE VOLTAGES ARE NOT CORRECT, YOU MUST RESOLVE THE PROBLEM BEFORE PROCEEDING!
5. Install the Si570. Be sure to align the “dot” on the Si570 with the “1” on the PCB. Center the Si570 on the pads and apply a small amount of solder to one pad and Si570 connection point. Then, before soldering the other connection points, check the alignment of all 8 connection points on the pads. Reheat and reposition the Si570 on the pads if necessary. Then solder the remaining 7 connection points. There three connection points on each side and one on each end.
6. Install MOSFETs Q1 and Q2. Orient per the silkscreen markings on the PCB.
7. Install the stereo phone jack, J1.
8. Construct the jumper assembly with 2 or 3 wires. One from tip-to-tip and the other from ring-to-ring. A ground connection wire is optional.
9. Plug Daughtercard into PIC-EL board.
10. (Optional) Software is not necessary for Si570 to generate RF at the Si570 default frequency of 10.0 MHz. If you have a frequency counter or a receiver that can tune to 10.0 MHz, power up the PIC-EL and verify that you have an RF output signal at 10.0 MHz. If not, stop here and find problem before installing the PIC. If you don't have a PIC-EL board, apply 12 volts to HDR1 pin 8, ground to the HDR1 pin 5, and look for the 10.0 MHz output on HDR1 pin 6.
11. Plug one stereo plug of jumper cable into the J1 of Daughtercard and the other jumper cable stereo plug into the “Paddles” jack of the PIC-EL board (J3).
12. Put the 16F88 PIC in 18-pin PIC socket of PIC-EL.
13. Program the 16F88 per PIC-EL instruction manual.
14. Switch the PIC-EL board PGM <-> RUN switch to RUN.
15. If you are using the AAØZZ Si570 Signal Generator software you MUST REMOVE THE 12v POWER FROM THE PIC-EL BOARD AND THEN RESTORE THE POWER AGAIN! This is important since it reinitializes and restarts the PIC program after programming. NOTE THAT THE PIC-EL RESET BUTTON DOES NOT START THE PIC PROGRAM since the Signal Generator program configures the PIC to use the PIC-EL RESET button as a functioning pushbutton instead of as a PIC RESET. The Signal Generator needs this button since two of the other three pushbuttons co-opted for use by the I2C communications via the “Paddles” connection.

4 PEgen570 Software Application

My sample application software for the AAØZZ Si570 Daughtercard is called PEgen570. It runs on a simple, inexpensive 16F88 PIC in the PIC-EL board.

As explained in Section 2.2, the daughtercard uses an external cable to communicate with the PIC-EL board.

4.1 A 16F88 PIC

There are several reasons why the 16F88 is used for this application instead of the PIC-EL standard 16F628A:

- 1) Compared to the 16F628A, the 16F88 has more than twice as much FLASH memory (for program instructions), 50% more data memory (for variable storage and tables) and twice as much EEPROM memory (non-volatile storage).
- 2) The 16F88 has an 8 MHz internal oscillator while the 16F628A has a 4 MHz internal oscillator. The extra speed is nice.

4.2 Band Tables

The software is implemented to use 24 frequency bands. Most of the parameters that the Si570 requires to produce the desired output RF signal are in tables in program memory. The program memory tables cannot be modified with program instructions. These tables are used by the application with the band number as an index.

One table is located in the PIC's data memory and can be modified. This table is loaded from EEPROM upon power-up. This table consists of 24 entries with each entry containing a starting frequency requiring 4 bytes. This means that the 24-band table requires 96 bytes of memory. Since the maximum size of any single bank of data memory in the 16F88 (or any "16F" PIC for that matter) is 96 bytes. This determines the maximum number of bands that can easily be handled in the PIC. With additional overhead the size could be expanded and then the upper frequency could be increased. However, the CMOS version of the Si570 (the version that the Daughtercard is designed to use) has a maximum frequency of 160 MHz. This means the current 96-byte table with an upper limit of 157 MHz is sufficient for this Si570 version. The lower limit of the Si570 is 10 MHz and the 96-byte table also handles this limit.

The 24 PEgen570 bands were created by examining the Si570 spec sheet and making calculations with a spreadsheet based on the Si570 parameter requirements. Without getting into the esoteric requirements of the Si570 frequency generating parameters and the formula involving several specific "multipliers", the Si570 internal crystal frequency and the desired output frequency, the frequency range of each band was calculated. The table was generated in such a way that the major parameters for each band can be pre-calculated and retrieved from tables when changing frequency. This greatly minimizes the number of complex calculations that must be done for each frequency change.

The 24 PEgen570 bands are defined as follows:

BAND	Frequency Range	BAND	Frequency Range	BAND	Frequency Range	BAND	Frequency Range
0	10 - 11 MHz	6	19 - 21 MHz	12	36 - 41 MHz	18	81 - 90 MHz
1	11 - 12 MHz	7	21 - 23 MHz	13	41 - 47 MHz	19	90 - 101 MHz
2	12 - 13 MHz	8	23 - 15 MHz	14	47 - 54 MHz	20	101 - 111 MHz
3	13 - 15 MHz	9	25 - 28 MHz	15	54 - 61 MHz	21	111 - 128 MHz

4	15 - 17 MHz	10	28 - 32 MHz	16	61 - 70 MHz	22	128 - 135 MHz
5	17 - 19 MHz	11	32 - 36 MHz	17	70 - 81 MHz	23	135 - 157 MHz

4.3 Si570 Calibration

The PIC's Si570 band tables described in Section 4.2 are pre-calculated with the nominal value for the Si570's internal crystal frequency (114.285 MHz). The table entries, combining the crystal frequency with other parameters needed to generate RF in that frequency range, are stored in the PIC's EEPROM and are loaded into the PIC's volatile memory at power-up. This nominal frequency is almost never perfect, of course, but the Si570 is calibrated in the factory to use corrected parameter values to produce the default start-up output frequency of exactly 10.0 MHz. (Other Si570 part numbers use different start-up frequencies.)

By holding Pushbutton 3 down during power-up, the application is directed to retrieve the parameters from the Si570's non-volatile EEPROM memory. The software then does a "reverse calculation" to find the actual Si570 crystal frequency as determined by the factory to produce 10.0 MHz. After the actual crystal frequency is determined, the table entries are recalculated and copied back to non-volatile EEPROM. When Pushbutton 3 is released, the PIC restarts and populates the tables with the newly calculated values.

4.4 User Interface

The user interface for the PEGen570 application is very simple. It uses two pushbuttons, an encoder, and a 2- line by 16-character LCD.

The "Reset" pushbutton on the PIC-EL board is configured (via the CONFIG statement in the source code) such that it does not perform a microprocessor reset when pressed but to operate as a normal I/O pin instead. This made the pushbutton available for operation and it is needed. To clarify this change in usage, the pushbutton will be referred to as Pushbutton 4 rather than the Reset pushbutton. This means that the 9PIC-EL board must be powered down and up after loading new software into the PIC before the new program will start executing. Simply moving the slide switch from PGM position to RUN position does not start the program.

The Pushbutton 3 and Pushbutton 4 are the two operational pushbuttons. When running the Si570, each time Pushbutton 3 is pressed and released the tuning digit that is currently being modified by turning the encoder to be increased by one digit. It can be advanced up to the 1 MHz position. Similarly, each time Pushbutton 4 is pressed and released, the tuning digit that is currently being modified by turning the encoder to be decreased by one digit. The digit that is currently being modified by the encoder is underlined.

When the daughtercard is running, pressing and holding Pushbutton 3 for longer than 2 seconds stores the current frequency in EEPROM. This frequency is used as the start-up frequency on subsequent power-ups.

4.5 Menu

A simple menu is used for changing mode between upper and lower sideband (USB, LSB, CW+ or CW-). Then the user can turn FSK on or off.

The menu is activated by holding Pushbutton 4 while pushing Pushbutton 3 and then releasing them both. The current mode is shown in character position 1 of line 1 of the LCD. Now, tapping Pushbutton 3 allows the user to toggle through the four sideband options, with the display showing U, L, + or -. Tapping Pushbutton 4 leaves this portion of the menu. If FSK mode is configured (by enabling a #DEFINE statement in the software source code), the current FSK state is displayed (either F or blank) in character position 1 of line 1 of the LCD). Tapping Pushbutton 3 toggles FSK mode between on and off. Tapping Pushbutton 4 once again exits the menu.

4.6 Sideband Select Relay

An external latching relay is engaged or disengaged as the sideband is changed in the menu. PIC output ports RA7 and RA6 attach to HDR5 and HDR6 (pins 16 and 15) respectively. As the sideband is changed in the menu, either RA7 or RA6 is driven high with a 8 mS pulse (with the opposite side being held low) to engage or disengage the external latching relay. The recommended latching relay (TQ2-L-5V – DigiKey part 255-1004-5-ND) requires 14 mA at 5v for 3 mS plus contact bounce time. The latching relay is intended to enable the proper I and Q phases of the transmitter and/or receiver to set the proper sideband.

4.7 Sidetone During Receive (or FSK shift)

Header HDR7, attached to PIC input port PB7, is monitored by the software to determine whether or not to shift the frequency by the sidetone amount if FSK is not active, or to shift the frequency by the FSK shift size if FSK is active. In CW+ or CW- mode, HDR7 is expected to be set to a low state by external Transmit/Receive circuitry during Receive operations and to a high state during Transmit operations. The software continually monitors the signal at HDR7 and, when is detected to be low while in CW- mode, shifts the frequency down by 600 Hz from the nominal, displayed frequency. If the mode is CW+ and HDR7 is low (Receive), the frequency is shifted up by 600 Hz from the nominal, displayed frequency. In either case, whenever HDR7 is detected to be high, indicating Transmit operation, the frequency will be set back to the nominal frequency that is displayed on the LCD.

When FSK mode is activated via the menu, the frequency is set to the displayed frequency when the signal on HDR7 is high (the MARK frequency) and is shifted down by 170 Hz when the signal on HDR7 is low (the SPACE frequency).

How fast does it switch? The software looks at the signal on HDR7 often enough to detect and change the frequency within 1.6 mS of HDR7 changing state. That's fast enough for QSK.

4.8 LCD Display

The first line of the LCD displays the current frequency. The second line is for debug purposes and shows the hex digits for the 6 Si570 register parameter (SiReg7 through SiReg12) starting at LCD position 1. The current band number is displayed in positions 15 and 16 of line 2.

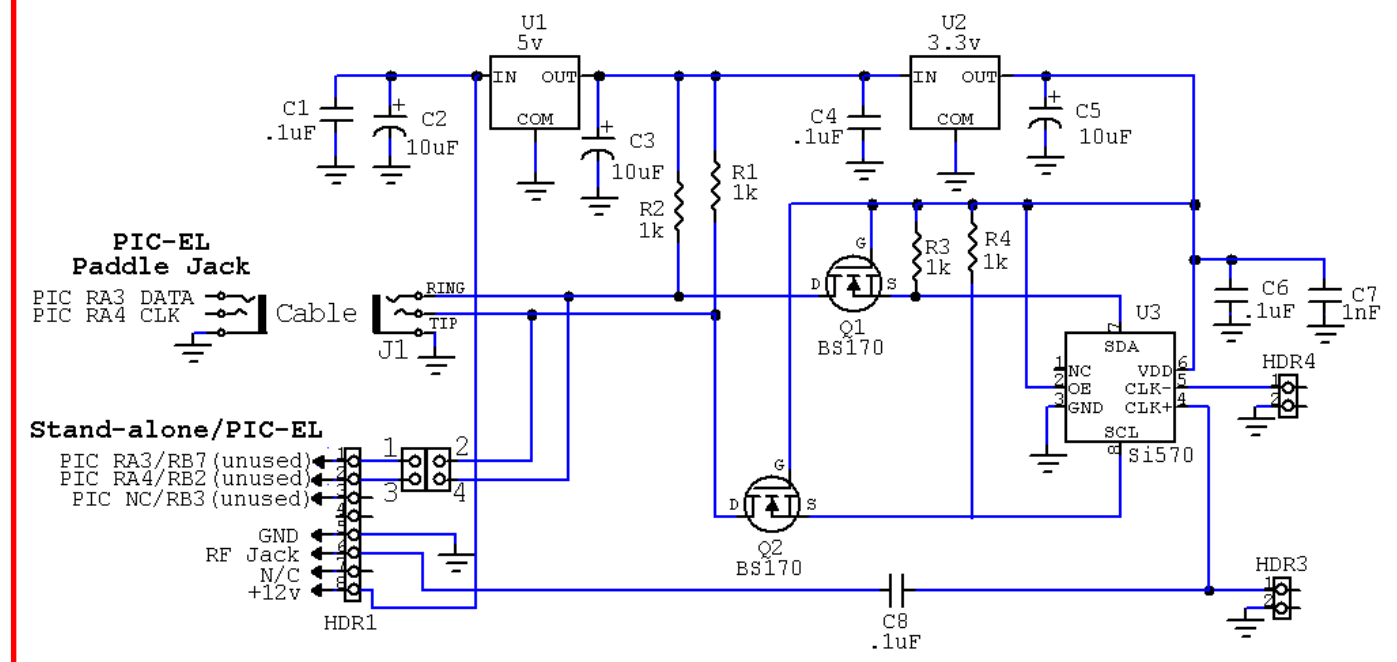
The PEgen570 application can be configured to display the Si570 frequency or it can be configured to display the Si570 frequency divided by four. The divide-by-four option is useful when the signal generator is being used as an signal source for a QSD/QSE ("Tayloe") mixer. The circuitry for these mixers usually divides the input frequency by four so this software option allows the LCD to display the mixer's operating frequency.

Appendix A – Schematic

AA0ZZ Si570 Daughtercard

Ver 4.4

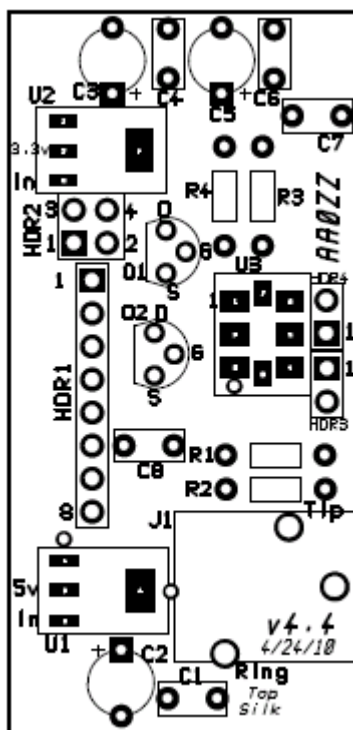
4/24/2010



Appendix B – Parts List

Si570 Daughtercard Parts				Ver 1.3	12/28/2010
Quantity	Designator	Description	Part number	Single Price	Total Price
1	HDR1	8-pin RA Header	(Samtec) TSW-108-08-F-S-RA	\$0.26	\$0.26
1	J1	Audio Jack 3.5mm	(D) CP1-3513N-ND (M) 161-3507-E	\$0.53	\$0.53
2	for I2C cable	Stereo plug 3.5mm Male	(D) CP-3502-ND	\$1.04	\$2.08
4	C1, C4, C6, C8	.1 uF ceramic cap	(D) 478-4855-ND	\$0.19	\$0.76
1	C7	.001 uF ceramic cap-axial	(D)1116PHCT-ND	\$0.08	\$0.08
3	C2, C3, C5	10 uF tantalum cap	(D) 399-3638-ND	\$0.79	\$2.37
4	R1-R4	1K resistor 1/8w 5%	(D) 1.0KEBK-ND	\$0.06	\$0.23
1	U3	Si570 CMOS 20ppm 10MHz	Silicon Labs 570CBC000107DG	\$25.06	\$25.06
1	U1	REG LDO 1A 5.0V SOT223-3	(D) ZLDO1117G50DICT-ND	\$0.62	\$0.62
1	U2	REG LDO 1A 3.3V SOT223-3	(D) ZLDO1117G33DICT-ND	\$0.62	\$0.62
2	Q1, Q2	BS-170 N-chan MOSFET	(D) BS170-ND	\$0.48	\$0.96
1	HDR2	pin header, 0.1", 2x2 pos'n	(M) 571-1032402	\$0.32	\$0.32
2	for HDR2	shunt, 0.1", 2 pos'n	(D) S9000-ND	\$0.08	\$0.16
3	for I2C cable	#22 Insulaed Hookup wire (3 colors, 7" each)	(D) A3051B-100-ND or similar	\$0.10	\$0.30
1	U1	PIC 16F88 (programmed)	(D) PIC16F88-I/P-ND with AA0ZZ software	\$7.50	\$7.50
1		PCB	AA0ZZ supplied	\$4.00	\$4.00
					=====
					\$45.85

Appendix C – Si570 Daughtercard Parts Placement



Appendix D – Si570 Daughtercard PC Board

