Orion-I Operation Manual (HW revision C, SW V1.4+)

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The Orion-I is a PLL synthesizer based on the ADF-4351 PLL chip. It utilizes an SiLabs C8051F531 microcontroller to control the synthesizer function via the PLL registers. The following lists the major specifications of this synthesizer:

Frequency range: 35 MHz to 4400 MHz
Output level: +15 ±2 dBm at 2000 MHz
Typical Phase Noise @ Fc = 800 MHz: -100 dBc/Hz @ 10KHz from Fc
Typical Phase Noise @ Fc = 3 GHz: -90 dBc/Hz @ 10KHz from Fc
Reference: 10.0000 MHz on-board (optional TCXO available)
        External reference selected by grounding J3-2 and may range from 10 MHz to 250 Mhz, +10dBm or 3.3Vpp(max), Zin = High-Z (>100KΩ)
Power supply: +7.5Vdc to 14.5Vdc, 250 mA (heatsink required for Vin above +8.5V)
Communications: UART com, 9600 baud, N81
Optional /PTT (/CH_ENABLE) input: GND true, 3.3V compatible, on-board pull-up, diode clamp /PTT (P2 pin 7) must be grounded for non-PTT operation.
Frequency select inputs: 2 digit, BCD (4 bits per digit), GND true, 3.3V logic
Primary connection: 16 pin ribbon header. Connector and cable not supplied. Connector P/N: TE/AMP 1658622-3, Ribbon cable, 16 conductor, 0.05" spacing, any vendor, length as needed (less than 12" recommended).
MCU PGM connection: SiLabs C2D on a 10-pin, 2 row, 0.1" connector. TE Connectivity P/N 5103309-1
Prototype Area: Severable from the main PLL board, this area is useful for modulation circuits (such as a CW ID'er or FM modulator) or other user constructed circuits.

Figure 1. Orion-I PLL Synthesizer

1 **Orion-I Operation**

Operation

The Orion operates from a 7.5Vdc (minimum), 14.5V (maximum) supply (tolerant of up to 26V for short periods). However, the PCB alone can only sustain operation up to a maximum input of about 8.5V. For operation above input voltages of 8.5V, one must attach an optional heat-spreader and heat-sink (see Appendix for details). All power and control signals for normal operation are available at the main connector, P2.

P1 Pinout

+3.3V	1	2	GND
GND	3	4	C2D
/RESET	5	6	P0.6
/RST_C2K	7	8	n/c
GND	9	10	n/c

P2 Pinout

+Vin	1	2	GND
RS-232_RXD	3	4	+5.0V out
RS-232 TXD	5	6	GND
/PTT	7	8	FSEL0 (LSD b0)
(LSD b1) FSEL1	9	10	FSEL2 (LSD b2)
(LSD b3) FSEL3	11	12	FSEL4 (MSD b0)
(MSD b1) FSEL5	13	14	FSEL6 (MSD b2)
(MSD b3) FSEL7	15	16	GND

Note: /RST_C2K and C2D are the SiLabs C2D programming protocol signals. P1 is required to allow MCU firmware programming.

Note: All logic signals are 3.3V logic and will NOT tolerate higher voltage logic

Frequency Selection (Channels)

The Orion functions as a 99 channel (channels 01 – 99), user-programmable frequency source with an "idle" channel (CH#00) which is selected when the /PTT input (A.K.A. /CHAN_ENAB) is open or above 2.5V. When /PTT is grounded, the channel data represented by the BCD code presented at the 8 FSEL inputs is transferred to the PLL. Each channel consists of six, 32-bit registers that are transferred to the ADF-4351 when the channel is selected. These six registers comprise the entire register set of the ADF-4351 and allow for complete control of the PLL functionality. Refer to the ADF-4351 datasheet for additional information regarding these registers.

It is recommended that users utilize the ADF-435x evaluation software provided by Analog Devices when defining a register set for a particular channel definition. From this software, the contents of the six registers can be copied to a spreadsheet for transfer into the Orion MCU. Programming the channels is covered in a later section of this document.

The 8-bit, 2-digit BCD logic inputs use the pull-up feature of the 8051 MCU to allow the PLL channel to be selected by applying GND (0V) or open (>+2.5V) levels to the FSEL inputs. To switch channels, simply apply the desired BCD bit pattern (using GND true logic) to the FSEL[7:4] (10's digit) and FSEL[3:0] (1's digit) inputs. *Note: the MCU will change channels immediately upon detecting a change in the channel setting. Thus, if individual bits are changed over even just a few ms, it may be possible for the Orion to select one or more unintended channels as the inputs settle.*

GND True means that a grounded bit = logic "1" and an open bit = logic "0". Thus, channel 18 would be set by grounding FSEL4 and FSEL3, with all other FSEL inputs open (A DIP switch or GND common BCD selector switch works well for this purpose).

Optional /PTT Function (CH00 Force: 2nd Frequency, or Mute)

If desired, the /PTT input can be used to switch the Orion PLL register set from the currently selected channel (/PTT = GND) to the register set programmed in CH00 (/PTT = open), and vis-à-vis. This feature is intended to operate as a mute input to the synthesizer, but any desired data can be programmed into CH00, so it could also serve many other functions as well (e.g., RX LO for /PTT = high and TX LO for /PTT = low). If the PTT function is not desired, the /PTT input must be grounded to permit the frequency select input to always be recognized and acted upon by the Orion software.

In order to accomplish the mute function, CH00 must be programmed with a register set that causes the PLL to mute its RF output. There are a number of different bit fields and patterns that can accomplish this. The following register set is the one used by the factory default software load to provide the mute function:

```
aaaaaaaa bbbbbbbb cccccccc dddddddd eeeeeeee ffffffff
00730010 08008029 00004E42 000004B3 00C50A04 00580005
```

CH00 can also be thought of as the "100th" channel of the Orion for applications where the PTT input is always grounded. CH00 then simply functions the same as the other 99 channels that are normally available and may be set to any desired PLL configuration.

Serial Port

The Orion MCU features a serial connection that can be used to program the MCU channel sets or to provide real-time frequency control of the PLL. An RS-232 transceiver is included on-board and this allows for an RS-232 serial connection to the Orion MCU. The wiring for this optional connection is described in the "MCU Programming Cable Connections" section. The serial parameters are 9600 baud, 8 data bits, no parity, one stop bit. At power-on, an initialization banner message is sent by Orion:

```
ADF4351 PLL Driver Ver 1.5, de ke0ff
100 CH, gnd-true BCD, PTT hi = CH00
Serial cmd enabled
pll>
```

3   **Orion-I Operation**

The reset banner provides the software version and a brief list of version features. Primarily, this message is important for identifying the current software version, and verifying that the UART TX connection to the user terminal is working. *Note: The banner message might change slightly with newer software versions.*

The serial commands available are as follows:

All commands are terminated with <CR> (ASCII 0x0d, <ENTER> or <RETURN> on most keyboards).
Serial port does <u>not</u> echo characters as they are entered.
Commands are 1 to 3 characters, case sensitive. Hex data may be upper or lower case.

?: List Command Help
Displays an abbreviated list of the available commands.

EA: Erase all channels
Prompts the user: "Erase all, press Y to accept…" and waits 5 sec for input. Any character other than upper-case "Y", or a delay of more than 5 sec will cause this command to abort with no changes to the system. This command must be executed if the channel(s) to be programmed contain any data other than all 0xFF.

E16: Erase channels 16 - 99
Prompts the user: "Erase CH16-99, press Y to accept…" and waits 5 sec for input. Any character other than upper-case "Y", or a delay of more than 5 sec will cause this command to abort with no changes to the system. This command allows a partial erase of the Orion channel space.

M: Program (memory) channel
`Mxxaaaaaaaabbbbbbbbccccccccddddddddeeeeeeeeffffffff`
P: Program (memory) channel from temp channel *(V1.5 and above)*
`Pxx`

Programs channel "xx" (xx is BCD ASCII '00' thru '99') with "a..a" (R0), thru "f..f" (R5) values (each register field MUST be 8 HEX digits in length. Add leading '0' digits if needed). Data is represented as ASCII hex ('0' thru '9', 'A' thru 'F', or 'a' thru 'f'). Space, comma, or TAB (ASCII 0x09) characters may be included between channel data characters for clarity, but the serial buffer limit is 62 characters per command line, including the command and channel# characters. If any invalid data is received, the command is aborted (with error message) and the channel is left un-programmed.

If the temp channel is valid, the "Pxx" command can be used to write the temp data to memory channel "xx".

Note: The "M" command processes one channel at a time. When uploading a file of programming commands, command lines that feature errors will not affect other command lines that are error-free. Also, a memory channel must be erased (0xFFFFFFFF in all register locations) before programming.

t: Temporary Channel

`t00aaaaaaaabbbbbbbbcccccccddddddddeeeeeeeeffffffff`

Programs the temporary channel using the same register syntax as the "M" command (the channel number, shown as "00" above, is ignored, but must be present). The temp channel allows a register set to be input to the Orion without programming a FLASH channel. Once set, the temp command overrides the BCD inputs. PTT behaves normally and will not change the temp channel configuration (/PTT high will select CH00, and /PTT low will select the temp channel when valid). Selecting a new BCD channel, or programming a channel with the "M" command will cancel the temp channel. The temp channel command must then be re-entered to re-enable the temp channel function.

z: Compare CRC

z hhhh

Compares the FLASH CRC to the "hhhh" value provided in ASCII hex (the CRC must be 4 digits). Displays PASS if there is a match or FAIL otherwise. If FAIL, the global error flag is also set. *Note: A one (1) second delay is provided to allow terminal upload to finish. As such, this should be the last command in an upload file if the CRC is known beforehand. If a 1 second delay is not sufficient, the "Q" command may be used to interrogate the pass/fail status of the upload.*

c: Calculate Channel Data CRC

c

Calculates a CRC-16 value (using 0x1021 for the polynomial) based on the 2400 bytes in the channel array stored in FLASH memory and displays the result to the serial port.

The MCU calculates the displayed CRC is by sequentially calling calcrc() (the code snippet below may be used to create an off-line CRC calculator if desired) with each byte in the array (2400 bytes, total), starting with CH00 R0 MS nybble (lowest address). "old_crc" = 0x0000 at the start of the calculation. *Note: The CRC16 result for all channels erased is 0xB2CF.*

```
//------------------------------------------------------------------
// calcrc() calculates incremental crcsum using defined poly
//       (xmodem poly = 0x1021)
//------------------------------------------------------------------
U16 calcrc(U8 c, U16 oldcrc){
#define POLY 0x1021    // xmodem polynomial

        U16 crc;
        U8     i;

        crc = oldcrc ^ ((U16)c << 8);
        for (i = 0; i < 8; ++i){
                if (crc & 0x8000) crc = (crc << 1) ^ POLY;
                else crc = crc << 1;
         }
         return crc;
}
```

5 **Orion-I Operation**

r: Read Channel Registers

`rxx`

Displays channel "xx" (xx is BCD ASCII '00' thru '99') in the same format as is used by the "M" command. Spaces are inserted between register fields for clarity.

r-: Read All Channel Registers

`r-`

Sequentially displays all channels starting at CH00. The resulting output is in the "M" command syntax format and may be used to archive or clone an entire channel set for a given Orion board.

rr: Read Temporary Channel Registers

`rr`

Displays temporary channel register values. Display format is:

`t00 aaaaaaaa bbbbbbbb cccccccc dddddddd eeeeeeee ffffffff`

i: Re-send last register set

`i`

Causes Orion to re-send the last selected resister set to the ADF4351 (/PTT = high: CH00; /PTT = low: the BCD or temporary channel set that was last selected).

e: Echo Command-Line (debug)

`e`

Echo command line. This is a debug command that will echo the characters on the command line after the "e" command and is useful in verifying UART operation.

Q: Query Error Status

`Q`

Displays FAIL if there was an error encountered in an "M" or "t" command. Otherwise, PASS is displayed.

QC: Clear Query Error Status

`QC`

Displays the current error status, then clears the status to PASS.

L: Query PLL lock Status

`L or l`

Displays PLL lock status: "L1" indicates PLL = locked, "L0" means PLL = unlocked.

While all of the previously listed commands may be typed manually, the "M" and "t" commands are mainly intended to be used by either manually downloading a text file containing the commands, or by using a special-purpose PC program to send the commands after processing them from either a text or spreadsheet input.

ADF435x Software

The ADF435x software is the easiest way to define a register set for the ADF-4351 and experiment with different ADF-4351 register settings. This software can be downloaded at no charge from the Analog Devices web site (see the Bibliography/Links section at the end of this document. *Note, a log-in account may be required, but is free to establish*).
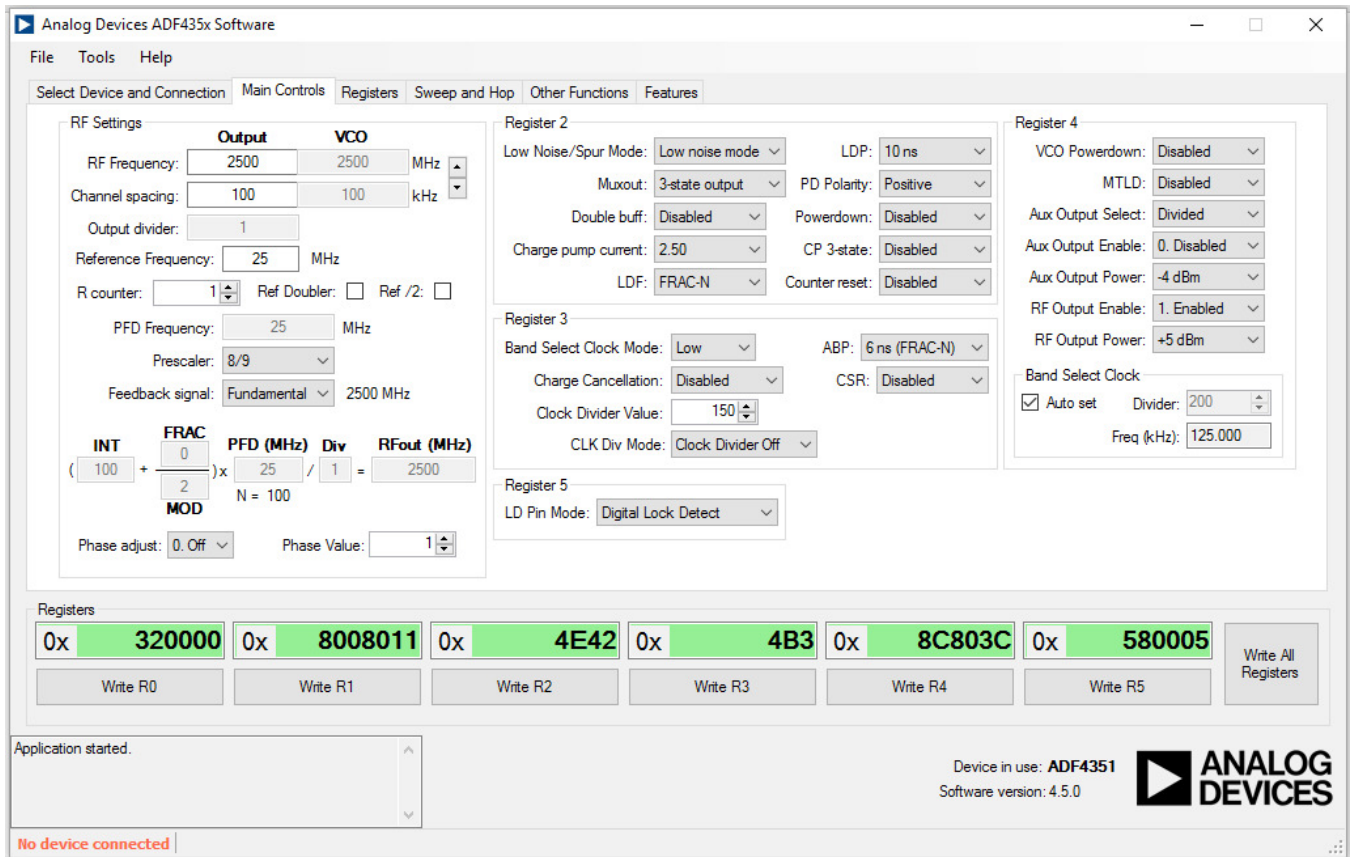

Figure 2. ADF435x Main Controls screen.

Figure 2 illustrates the Main Controls screen of the software. *Note: this software has the ability to communicate directly with the Analog Devices Evaluation board for the ADF-4351. However, this functionality is not available with the Orion board.* In general, most of the default settings can be used. The main items that must be filled in for a given frequency are as follows:

7   **Orion-I Operation**

RF Frequency: Enter the desired output frequency in MHz

Channel spacing: This should be at least an even multiple of the RF Frequency

Reference Frequency: 10 MHz for the standard Orion configuration (if a different reference is used, then that value is entered)

PFD Frequency: Should be the same as the Reference frequency

RF Output Power: This is selectable in 3 dB steps from -4 dBm to +5 dBm. It is recommended that this value be LESS THAN +5 dBm unless the user is prepared to monitor the operating temperature of the ADF-4351 to make sure that its temperature limits are not exceeded.

MTLD: (optional) This feature mutes the RF output (to less than -40 dBm) until the PLL lock detect is TRUE.

Refer to the ADF-4351 datasheet and ADF435x help files for explanations of the other fields on this screen.

The ADF435x software updates the register settings (displayed along the lower portion of the screen) in real time as the fields are updated. Settings that result in an illegal configuration or other known conflict will be indicated by a small "!" icon near that field. The user may hover their mouse pointer over the "!" icon for a detailed message as to the nature of the problem.

Constructing an Upload File using the Orion Excel Spreadsheet

A spreadsheet is available for Microsoft Excel (2013 or later) that allows the user to enter register values copied from the ADF435x Software or the integrated ADF4351 tab may be used to construct the register definitions for each channel. Other tabs in the spreadsheet create an output file that is ready for upload (complete with CRC check) to the Orion-I or an Intel HEX output option is also available for use with the SiLabs MCU programming system (optional). This spreadsheet is available at www.rollanet.org/~joeh/projects/Orion/ under the "Channel Programming Spreadsheet" link.

Manually Constructing an Upload File

Once all of the fields in the Main Controls window have been set to the desired values, the user may copy the registers into a text file to manually build up the command line for writing to the Orion memory. One can use their mouse pointer to select the contents of the registers in the Main Controls window (click-hold, drag across the register value, and release, followed by COPY, or CNTL-C), but this must be done for each individual register. *Note: all of the references to "Write" in the ADF435x software refer to writing the values to the evaluation board, not writing them to a file.*

In addition to manually copying the values, the user must add leading zeros to the values so that each register value is exactly 8 digits in length. Also, DO NOT pre-pend the C-style "0x" hex specifier to the register values. The following is an example of the process (it is helpful to use a non-proportional font such as Courier and paste the syntax field

above the data to be edited, as shown below… this syntax field should not be included in the file to be uploaded):

144.100 MHz, 5 KHz spacing, 10 MHz REF, +2 dBm:

```
aaaaaaaa bbbbbbbb cccccccc dddddddd eeeeeeee ffffffff   <-- syntax fields
730070 80080C9 4E42 4B3 C50034 580005                   <-- data
```

Note that spaces were manually added between the registers. Next, add leading zeros to line up the data with the "syntax fields":

```
aaaaaaaa bbbbbbbb cccccccc dddddddd eeeeeeee ffffffff
00730070 080080C9 00004E42 000004B3 00C50034 00580005   <-- leading 0's added
```

Finally, add the command prefix: for the FLASH channel write, add "Mxx" (no spaces between the characters) where "xx" is the desired channel#, or "t00" for the temporary channel. The following depicts the same register set for both a FLASH channel and the temporary channel:

```
M01 00730070 080080C9 00004E42 000004B3 00C50034 00580005
t00 00730070 080080C9 00004E42 000004B3 00C50034 00580005
```

Comments may be added to the file. Make the first character of comment lines a ";" and limit the comments to 60 characters per line. Note: The 60 character limit applies to all command lines for the Orion board. Also, to help prevent crashes during file transfers, keep the number of added spaces in command lines to a minimum. There is no limit to the number of comment lines, but just be aware that the comment lines add to the file transfer time. The following is an example of a finished channel write command:

```
;144.1 MHz, 5KHz chspc, 10MHz ref, +2dBm
M01 00730070 080080C9 00004E42 000004B3 00C50034 00580005
```

These command lines and any comments can be placed into one text file. All 100 channel locations may be programmed by a single upload operation, or multiple files may be used. *Note: The Orion software does not check for erased locations before programming. Thus, attempts to write different data into the same channel, either in the same upload file or in separate files, will result in corrupted data for that channel.*
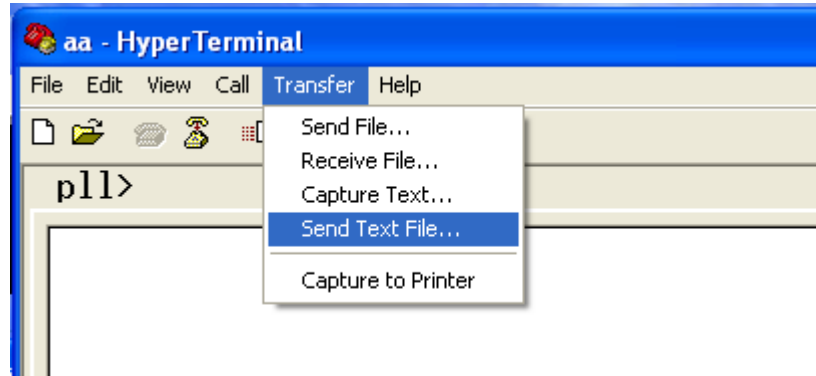
Figure 3. Hyperterm text file transfer selection

To write the file to memory, first connect power to the Orion board and connect the PC COM port (9600, N81). After the power on message is observed, type "E" and then "Enter" (CR). Type "Y" at the "`Erase all, press Y to accept…`" prompt. Next, issue the "QC" command to clear the error status. Then, perform a text file upload using the terminal program of choice (for Hyperterm, see Figure 3).

Some terminal programs will display the terminal progress as the file uploads (Hyperterm does this). If so, the "`Chan pgmd!`" message should be observed after each "M" line is transferred.

Once the file transfer is complete, one should perform a "Q" command to verify that there were no errors encountered in the downloaded data. The CRC16 check ("c" or "Z" command) should also be performed. Note: The "Orion Channel Workbook" spreadsheet will include a "Z" command with the pre-calculated CRC for the data in that file. This will display a "PASS" or "FAIL" message 1 second after the transfer finishes.

For the temporary register feature, one may follow the above steps to transfer the register set into the Orion, or use the "Orion Channel Workbook" spreadsheet to create the command line.

 Orion-I Operation

Factory supplied channel settings - unless noted, all channels are configured with a 10MHz reference at -1dBm output (about +9 dBm at J2):

Chan	Freq	Chan	Freq	Chan	Freq	Chan	Freq
00	RF off	25	3000 MHz†Δ	50	empty	75	empty
01	144.1 MHz* Δ	26	empty	51	empty	76	empty
02	1152 MHz	27	empty	52	empty	77	empty
03	1872 MHz	28	empty	53	empty	78	empty
04	2160 MHz	29	empty	54	empty	79	empty
05	3024 MHz	30	empty	55	empty	80	empty
06	3312 MHz	31	empty	56	empty	81	empty
07	1776 MHz, +5dBm	32	empty	57	empty	82	empty
08	1872 MHz, +5dBm	33	empty	58	empty	83	empty
09	3312 MHz, +5dBm	34	empty	59	empty	84	empty
10	3408 MHz, +5dBm	35	empty	60	empty	85	empty
11	empty	36	empty	61	empty	86	empty
12	empty	37	empty	62	empty	87	empty
13	empty	38	empty	63	empty	88	empty
14	empty	39	empty	64	empty	89	empty
15	empty	40	empty	65	empty	90	empty
16	34.375 MHz*	41	empty	66	empty	91	empty
17	432.1 MHz*	42	empty	67	empty	92	empty
18	902.1 MHz*	43	empty	68	empty	93	empty
19	1296.1 MHz*	44	empty	69	empty	94	empty
20	2304.1 MHz*	45	empty	70	empty	95	empty
21	3456.1 MHz*	46	empty	71	empty	96	empty
22	1920.0333 MHz†Δ	47	empty	72	empty	97	empty
23	3456.0333 MHz†Δ	48	empty	73	empty	98	empty
24	3000 MHz†	49	empty	74	empty	99	empty

* - These channels are at -4 dBm (about +6 dBm at J2)

† - These channels are at +5 dBm (about +15 dBm at J2)

Δ indicates an 8/9 prescale mode. All others are 4/5.

Note: Version 1.6 and above supports a "Find Highest Numbered Channel" mode. If the BCD code on FSEL0-3 is invalid (e.g.: %1010, %1011, %1100, %1101, %1110, or %1111), the system will start at CH99 and search downwards until it finds a channel that has data programmed in register 5. This channel will then become the active channel. This is done automatically each time the BCD inputs change state. For systems that actively change the BCD settings, care must be exercised to make sure an invalid BCD code is not presented to the FSEL0-3 inputs (invalid BCD codes on FSE4-7 will not activate this feature). Changing the BCD code only while /PTT = 1 (open) will prevent any possibility of unexpected codes being recognized by the software. The PTT operation is not altered by this feature.

For example: If the above table is programmed as shown, and FSEL3 = FSEL2 = GND (an invalid BCD code, regardless of the state of the other FSEL inputs), the system will select channel 25 if /PTT = GND, and CH00 if /PTT = OPEN.

MCU Programming Cable Connections

In order to program the MCU software or channel data using the MCU programming tools, the SiLabs programming adapter and software are needed. The programming adapter is available from DigiKey or Mouser under the part number "DEBUGADPTR1-USB" (cost is about $35). The software can be obtained from the SiLabs web site at: http://www.silabs.com/products/mcu/Pages/8-bit-microcontroller-software.aspx

The debug adapter connects to P1. Follow the programmer instructions to upload a new FLASH program to the MCU.

When only the channel data is to be programmed, this may be accomplished by the UART serial connection which does not require the SiLabs programming adapter.

UART Connections

The UART RXD and TXD connections are available at P2-3 and P2-5, respectively. To exercise this option, wire a DSUB-9, female connector (such as the Amphenol L77SDE09S, or equivalent, available from Mouser) per Figure 4.

RS-232 Pinout (D-SUB9 Female)

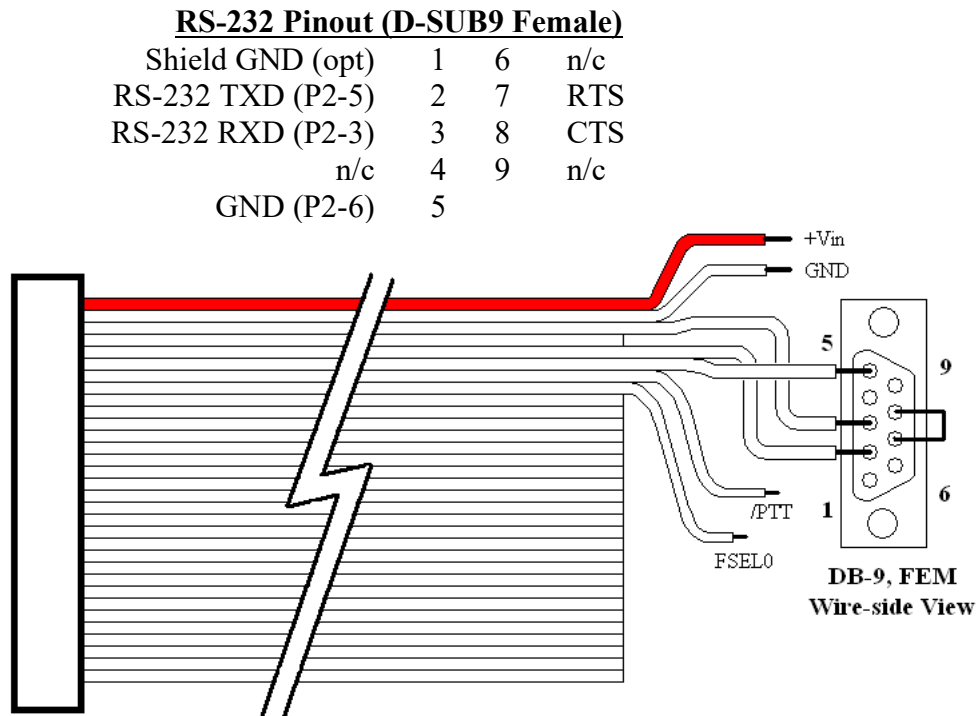|			
Shield GND (opt)	1	6	n/c
RS-232 TXD (P2-5)	2	7	RTS
RS-232 RXD (P2-3)	3	8	CTS
n/c	4	9	n/c
GND (P2-6)	5		

Figure 4. RS-232 cable wiring

For most PC serial connections, RTC/CTS are left disconnected. However, some connections may require these signals. In this case, simply connect the D-SUB9 pin 7 to pin 8. Cable lengths should be no longer than needed to be accessible for connection to a standard RS-232 cable.

Orion-I Operation

Partial Kit Assembly Instructions

The partial kit version of the Orion-I comes with all top-side SMD components attached, and the MCU programmed. The kit-builder need only install the top-side thru-hole components and the bottom side SMD components to complete the assembly. Items supplied by the kitbuilder: A temperature controlled soldering iron, a pair of tweezers, solder (63/37 no-clean is best, but 60/40 rosin core is acceptable), a magnifier (e.g., a magnifying lamp, +3.0 (or greater) reading glasses, or a magnifying loupe), about 2.25 inches of 0.01" OD heat-shrink tubing, and a razor knife.

A checklist is provided that lists all of the components provided. Refer to Figure 5 for illustrations of the SMD component markings. The SMD components are supplied taped to a paper carrier. It is recommended that these components be left in this state until ready to attach. Also, only remove one part at a time (by cutting the tape around the part with a razor knife) to prevent confusion as to which part is which. Use care when gripping the SMD parts. Once they make a flying leap, they can be very difficult to locate.

Some Orion boards are supplied with a score line (top and bottom side) between the main board and the prototype area. If the prototype area is not needed, place the prototype side of the board into a bench-vise using a pair of smooth, clean angle aluminum pieces (each at least 4" long) to protect the circuit board from the vise jaws. The top side of the board should face toward you. Align the score line to be just above and parallel to the edge of the angle aluminum. Use a piece of ¾" plywood that is at least the size of the Orion board against the bottom side of the PCB. Keep the plywood in close contact with the PCB and carefully "hinge" the plywood by moving it so that it pivots at the score line. Favor one side of the score line until the board begins to fracture. Continue the "hinge" motion until the entire length of the PCB has fractured. Use a small piece of 150 grit sandpaper to clean the severed edges. Do not allow the PCB to bow or the SMD components may be damaged.
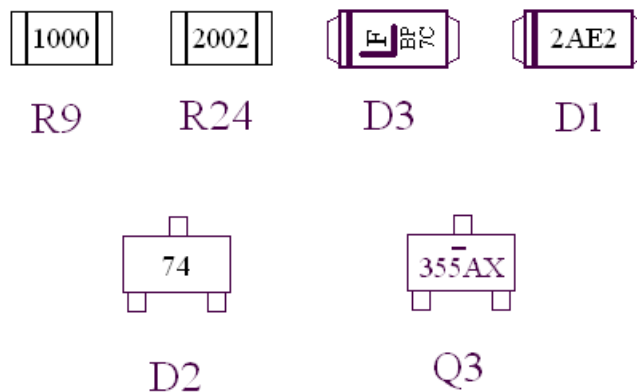

Figure 5. SMD component markings (not to scale). Stripes on the diodes correspond to the beveled edge on the silk-screen legend.
Note: These are example component markings. Actual markings may differ.
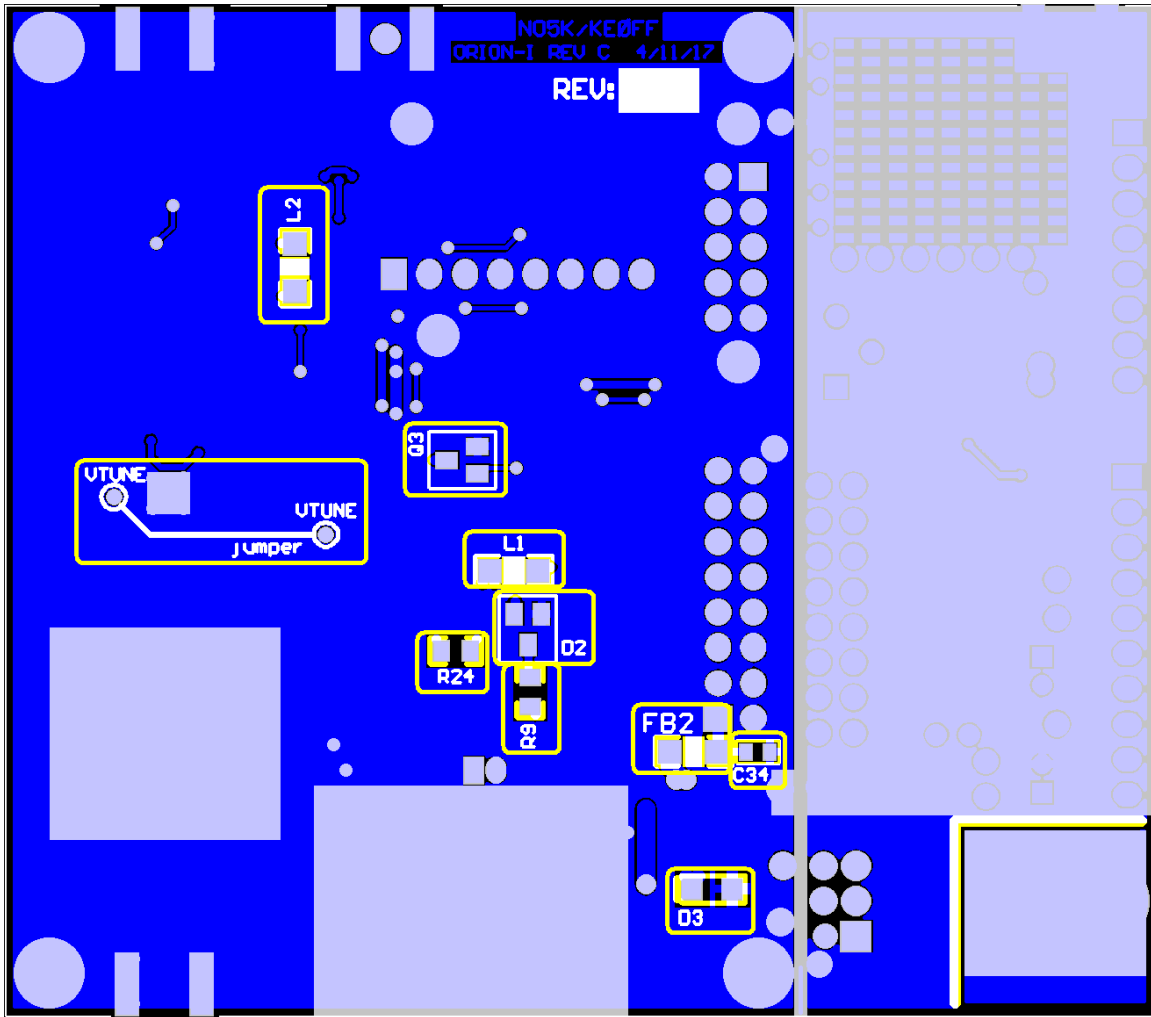
13 **Orion-I Operation**

Figure 6. Orion bottom side components (encircled components are installed by kit-builder)

On some kits, D1 (top side, next to the 5V regulator, U11) must be installed by the kitbuilder. If D1 is missing on the PCB, it should be included in the kit parts and thus should be attached first (be sure to note the polarity when attaching). Next, solder the bottom-side SMD components (including the VTUNE jumper wire). The bottom side view is illustrated in Figure 6. The order of attachment is not critical. Once the bottom SMD components are attached, the top-side thru-hole components may be attached (*Note: P1 may be pre-attached on some kits. In this case, nothing need be done to P1*). Some might find it helpful to install the 0.5" threaded spacers on the top side of the board to hold the board steady while soldering the through-hole parts. See Figure 7 for an illustration of the top-side component placement. Be sure to note the component orientation for pin 1 (J1 and J2 are oriented opposite from one another) or polarity before installing (Note that the "+" pad is indicated for C43, but the part has a white stripe on the "-" side of the capacitor). Solder all connections and then trim the leads where

14 **Orion-I Operation**

needed. The "-" pad for C43 has rather small thermal reliefs, so it may be necessary to supply a bit more heat to this connection for proper solder wetting.
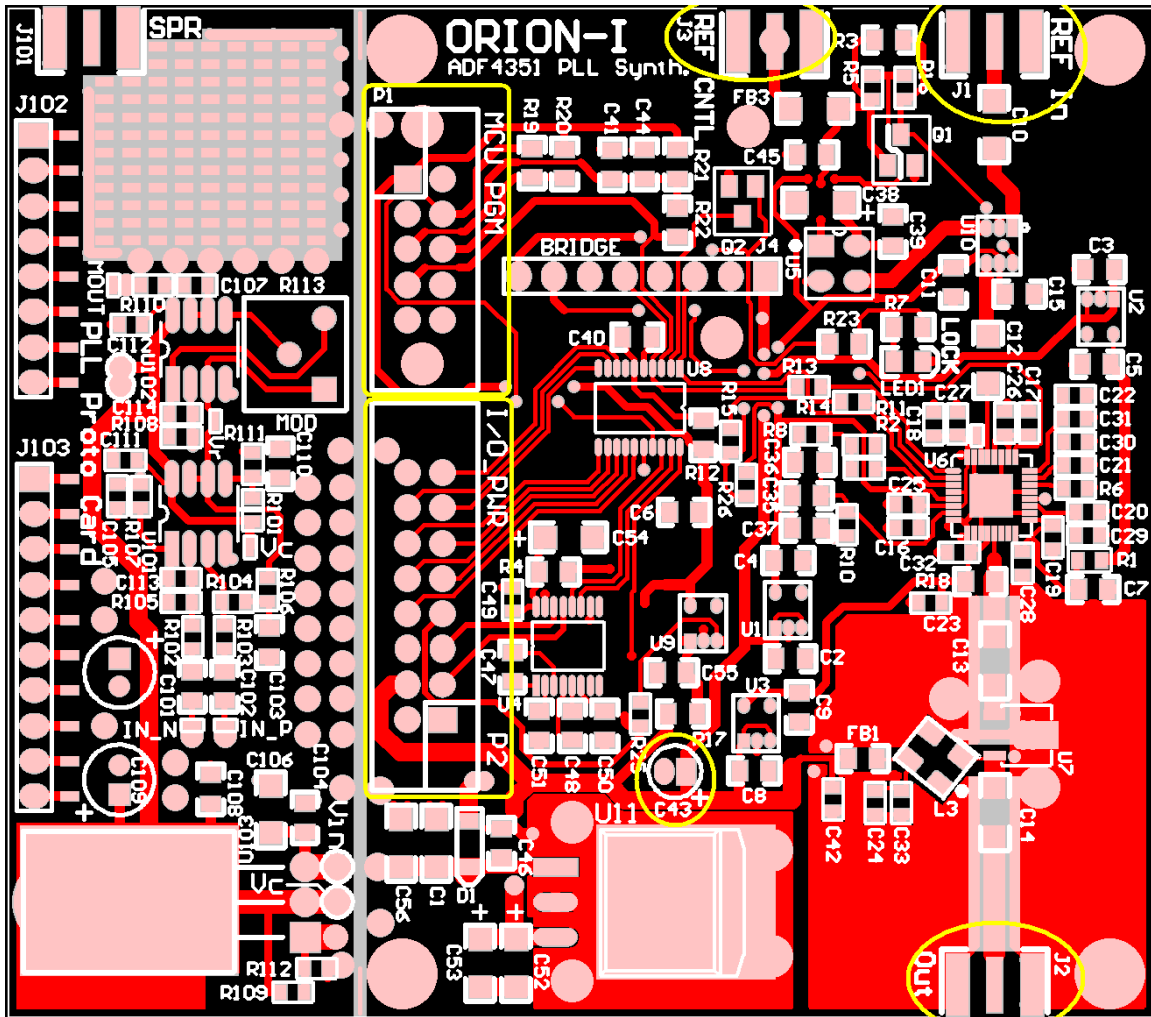

Figure 7. Orion top side components (encircled components are installed by kit-builder)

A high-temperature tip is recommended for the edge mount SMA connectors. Be careful not to overheat the connector housing or PCB.

Perform an ohm-meter check of the 5V regulator (U11). Pin 1 (near C46) to GND (U11-TAB) and Pin 3 (near C52) to GND should both read greater-than 1 KΩ (steady). If either reading shows less-than 1 KΩ, check the soldering for bridges. Correct the problem before applying power to the Orion board.

Once all of the components are placed and the ohm-meter checks pass, the Orion is ready for use. Separate the wires of the ribbon cable approximately 1" and strip 0.1" from the leads corresponding to P2-1, P2-2, P2-7, and P2-8 (refer to Figure 4). *Note: The ribbon conductors follow the P2 pin numbers starting with pin 1 at the red-stripe of the ribbon cable.* Next, ground P2-8 (FSEL0) and connect P2-1 (+V) to the positive supply, and P2-

15   **Orion-I Operation**

2 (GND) to the supply return. If desired, connect a female DB-9 connector to allow a terminal connection to the Orion. It is recommended that a continuity check be performed to verify the power connections to the solder side of P2 (pin 1 of P2 features a square pad). Apply power and ground P2-7 (/PTT) and note that the Lock LED should light and the PLL RF output should be produced on 144.1 MHz, at about +6 dBm. Any 2m receiver (even FM) that can tune this frequency can be used to confirm the presence of this signal (a small antenna connection to the Orion RF connector might be needed if the receiver antenna is more than a few feet away). Removing P2-7 from ground should extinguish the lock LED and there should be no output from the Orion RF connection. *Note: the /PTT action of the Orion is rather slow, so the /PTT is not generally suitable for sending Morse code.*

A DIP switch or other switch mechanism may be connected to the FSEL pins of P2. Connect /PTT to a grounded switch, or ground it permanently to enable channel selection. The +5V output (P2-4) can power external circuits, but every mA supplied to this pin increases the heat-load on U11. The max current that can be supplied is about 200 mA, but this should generally be limited to less than 10 mA unless a thermal solution is verified for U11. Failure to follow these guidelines could result in failure of the U11 regulator, and possible damage to other components.

Bibliography/References

- ADF435x Software:
    - https://ez.analog.com/servlet/JiveServlet/download/10667-1-30579/ADF435x_v4_5_0.zip
- ADIsimPLL:
    - https://form.analog.com/form_pages/rfcomms/adisimpll.aspx
- SiLabs C8051F531 Datasheet and Programming Manual (search for C8051F531):
    - http://www.silabs.com/products/mcu/Pages/default.aspx
- Analog Devices ADF4351 Datasheet and UG-435 Evaluation Board User Guide:
    - http://www.analog.com/en/products/rf-microwave/pll-synth/fractional-n-plls/adf4351.html
- Mini-Circuits GVA-62+ Datasheet:
    - http://www.minicircuits.com

Appendix A
Installation and Application Notes

The Orion mounting holes are sized for 2-56 screws (0.11" diameter clearance hole). Figure 8 illustrates the outline drawing of the Orion including mounting hole locations. 8 screws and 4 standoffs are included with the Orion kit. Replacement screws and standoffs may be obtained from McMaster-Carr (www.mcmaster.com) or other hardware supplier:

Screws, 2-56 x 0.250" (McMaster PN: 91772A077), QTY 8
Standoffs, 2-56 x 0.500" (McMaster PN: 91780A032, QTY 4 (1/2")

Depending on the application, washers and lock-washers may also be recommended (these are not included with the Orion kit). As mentioned earlier, a heatsink for U11 is required for power supply voltages that exceed 8.5V. The Orion has provision for a back-side heat-spreader and subsequent heatsink. A mounting kit is available that includes a 0.5" thick heat spreader and mounting standoffs. If the heat-spreader is attached to a large chassis base (at least 4" square) that consists of 0.06" thick (or thicker) aluminum, a heatsink may not be required.

Figure 8. Orion Dimensions
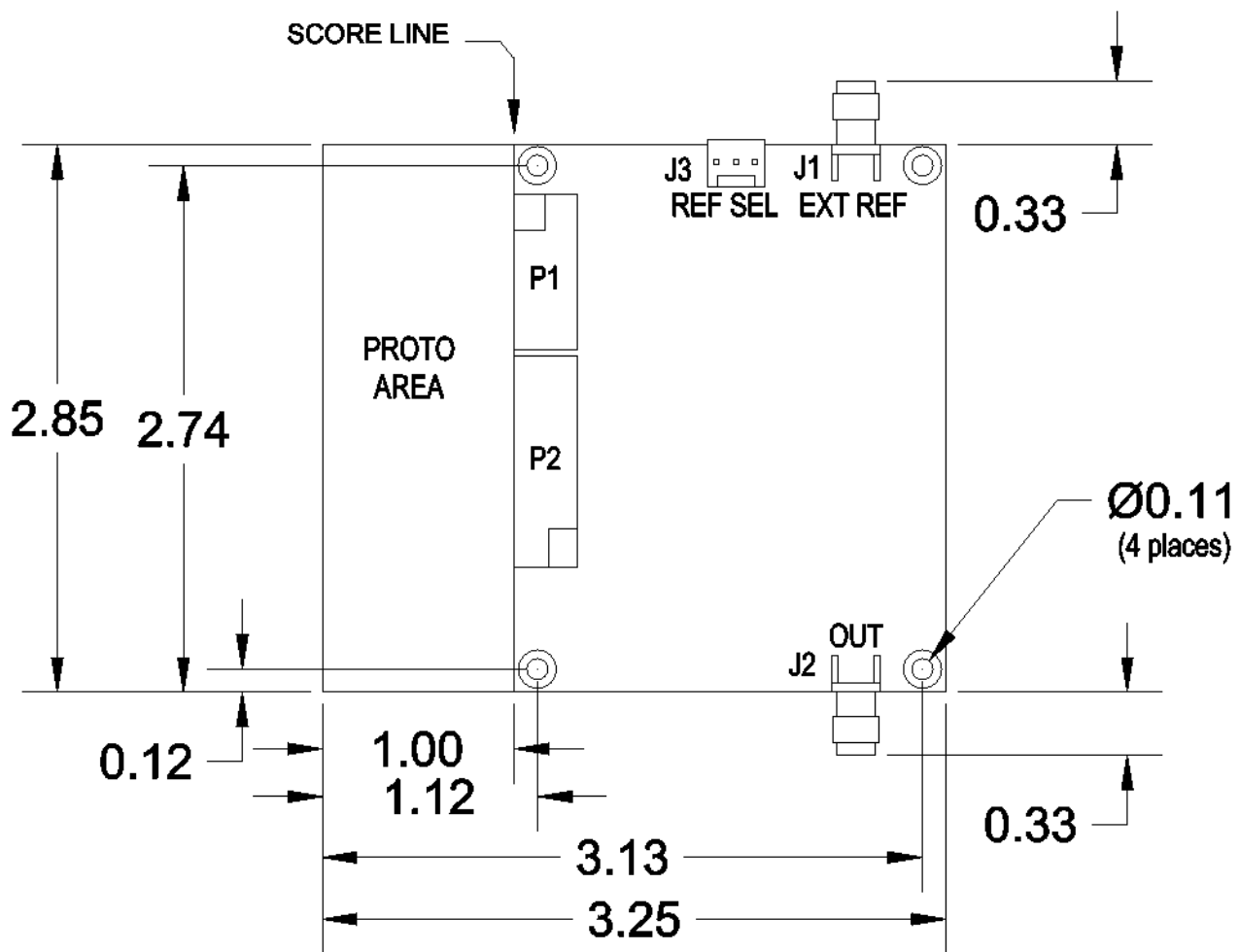
An alternative to the heat-spreader is for the kit-builder to install the LM317 (with a suitable heatsink) into the Orion prototype area and configure it to supply 8.5V. This "pre-regulator" output (available at the "Vc" pad located near the center pin-pad of U103) would then be connected to P2-1 via a user supplied jumper wire (in this case, do not use P2-1 to supply power to the Orion unless D1 is removed and re-located to route power from P2-1 to the "Vin" pad of the prototype area). The pre-regulator would reduce the heat-load on the U11 regulator without the need for a bottom-side heat-spreader. The prototype area can be left attached, or separated from the main Orion PCB and mounted as a separate sub-assembly.

Pre-regulator BOM:

Designator	QTY	Part Type	Footprint	MFR P/N
C104, C108	2	0.1uF, 25V	0805	C0805C104K3RACTU
C106	1	10uF, 50V	1206	GRM31CR61H106MA12L
C109	1	100uF, 25V	RB.8/.12	UVK1E101MDD
R109	1	RES, 243Ω	0603	RC0603FR-07243RL
R112	1	RES, 1.400KΩ	0603	RC0603FR-071.4KL
U103	1	REG, Volt, ADJ	TO-220	LM317AT/NOPB
-	1	Heatsink, TO-220	TO-220	272-AB (Wakefield-Vette)
-	1 (lot)	TO-220 mounting hardware: 4-40 x 3/8" screw (1), 4-40 nut (1), #4 flat washer (2), #4 lockwasher (1)	-	(various)
-	1 (opt)	TO-220 insulating kit	-	4724 (Keystone)
-	1 (opt)	Thermal gap-filler compound	-	(various)

Note: The prototype ground plane is separate from the Orion main board ground-plane. Refer to Figure 10 for the location of ground pads that can be used to bridge the Orion main ground to the prototype area ground.

Digital OFF Feature

The Orion has the ability to be configured such that the digital circuits (U4, U8, and associated components) can be switched off with an open/GND input. This reduces the power required by the Orion somewhat. More importantly, it reduces the power supply noise that might couple into the PLL circuits. This would be recommended for LO applications where the Orion channels are not likely to change often (if at all). The Orion features significant filtering on the digital power, but it is possible that some improvement in output noise might be achieved by turning off the digital circuits once the PLL has been initialized.

To utilize this feature, the /PTT input (P2-7) is re-tasked as a /DIGITAL_OFF signal. Simply move R9 to R25 (not populated by default). Alternately, R9 can be removed and R25 replaced with a new component of approximately the same value. The /PTT input to the processor must then be grounded

 Orion-I Operation

with a short jumper wire as shown in Figure 9. Grounding P2-7 will then disable the power to the digital circuits, and leaving P2-7 open or at 5V will apply power to these circuits.
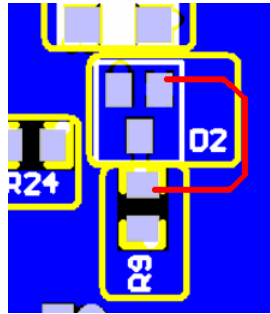

Figure 9. Ground /PTT by adding a short jumper from R9 (now removed) to D2 as shown

An external N-CH FET, and RC network can be used to allow a power-on period where P2-7 is open, which allows the MCU to power up and send data to the PLL chip, then go to ground disabling the digital circuits. The PLL will continue to operate, but the digital features will not respond while P2-7 is grounded by the transistor.

A transistor, such as the NDS355, would be wired as shown in Figure 10. Choose RC > 0.25 to allow sufficient time for the MCU to power on and configure the PLL. For example, R = 30.1 KΩ and C = 10 µF should provide sufficient delay to allow the PLL to configure once power is applied. An optional momentary switch to GND and a series 100 ohm resistor connected to the transistor gate would allow one to "re-start" the PLL by temporarily applying power to the digital circuits for as long as the switch is closed.
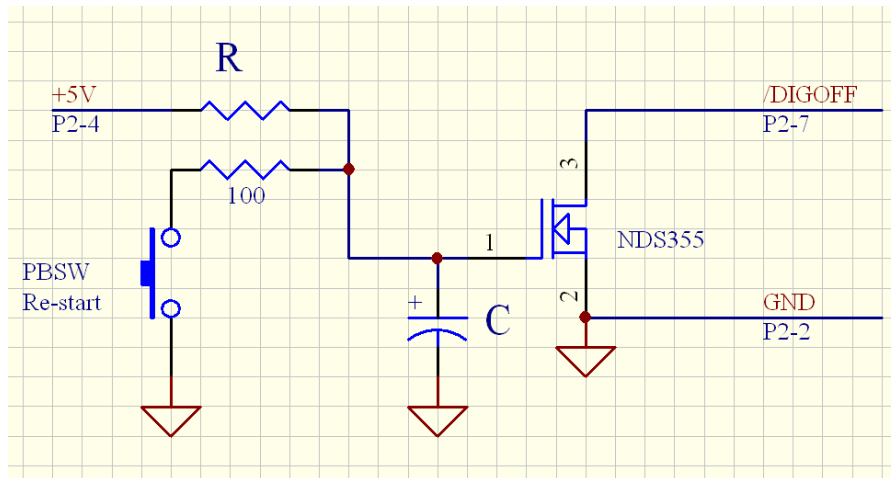
Figure 10. Digital-off power-on start circuit (components provided by kit-builder)

Alternately, the above circuit could be placed in the Orion prototype area and the "/DIGOFF" connection of the N-FET wired directly to U9-3 (in this case, none of the other modifications to R9 or R9/D2 would be performed). This would preserve the function of the /PTT input (if desired). *Note: any change to the /PTT status would only be recognized while the MCU is powered-on.*

19   **Orion-I Operation**

RF Filtering

The Orion PLL is an excellent signal source with a very wide tuning range (almost 126:1). The Orion is suitable for a transverter or transceiver LO source, or a lab instrumentation source. Software is available to produce frequency sweeps to allow the Orion to sweep filters or other circuits of interest. There is also a beacon application that allows the Orion to send a repeating, keyed CW message suitable for operating as a beacon exciter. *Note: Orion Software changes require the SiLabs programming adapter (approximately $35 from DigiKey or Mouser) and the SiLabs FLASH programming utility program (the software is available for free from www.silabs.com).*

For all of its flexibility, there is one thing that must be considered when using the Orion: filtering is required to reduce the harmonic output of the PLL. For most low-noise applications, the harmonic output can be as high as -16 dBc or more. For instrumentation applications, this may not be a serious issue. However, for communications transceiver applications, these spurs must be reduced to preserve signal purity and system performance. Generally, a suitable low-pass filter will have an Fc somewhat above the desired output frequency (to reduce pass-band attenuation) and a stop band that extends to at least 5Fc. At least 30 dB at 2Fc and 35 dB of stop-band attenuation at or above 3Fc is a good general purpose target for most applications. This will generally provide -45 dBc or better harmonic perfomance.

Small SMA filters, such as the MiniCircuits VLF-1400+, are easy to implement, and are not terribly costly – they simply attach to the Orion output. MiniCircuits (and others) also offer ceramic chip filters that are rated at 50 ohms. For LO and other mixer applications, reflectionless filters are recommended as these present a consistent input/output impedance even in the stop-band. However, these can be more difficult to find and implement, so they are not often an easy option. A buffer with high-isolation can be used after the filter if it is a good match to 50 ohms in the stop-band. This may also require an attenuator if the buffer produces too much signal for the mixer. The attenuator should follow the buffer if possible and should offer a good output match across the entire bandwidth of the mixer.

Filtering for wide bandwidth applications (about an octave of bandwidth or greater) is difficult to manage. This is because the output frequency varies over the harmonic range of the lowest desired output. This means that a filter that is good for the lower frequencies will attenuate the higher frequencies and a filter optimized for the higher frequency will not provide sufficient attenuation to the 2nd harmonic. In these cases, either a switched filter arrangement or a tunable filter, such as a YIG Tuned Filter (YTF), must be used. Both options represent a complicated compromise that will require considerable care and effort to produce.

Fortunately, most wide-band applications are geared towards instrumentation where other instruments that are part of the measurement suite might be expected to provide some semblance of filtering or other immunity to harmonics emitted by the Orion reference source.

Prototype Area

The prototype area holds component patterns for optional circuits that can be used to frequency modulate the Orion output, produce wave-shaping signals for CW applications, produce regulated supply voltages for bias or sequencing circuits, or any other small ancillary circuit needed by the project.

 Orion-I Operation

The prototype area features a substantial ground-plane, but this net is not connected to the main Orion ground net. For applications which make use of the prototype area, the kit-builder must connect the main Orion ground to the prototype ground. There are 4 locations established for this purpose and these are identified in Figure 11. Simply solder a short piece of bus-wire between the indicated pads to connect the two grounds together.

For applications which use the LM317 voltage regulator (other than the pre-regulator option mentioned previously in this document) connect the input to the LM317 to the P2 power input by bridging the two pads that straddle the score line next to the "Vin" pad and C56. "Vc" is the regulator output and this output is also routed to the op-amp circuits.
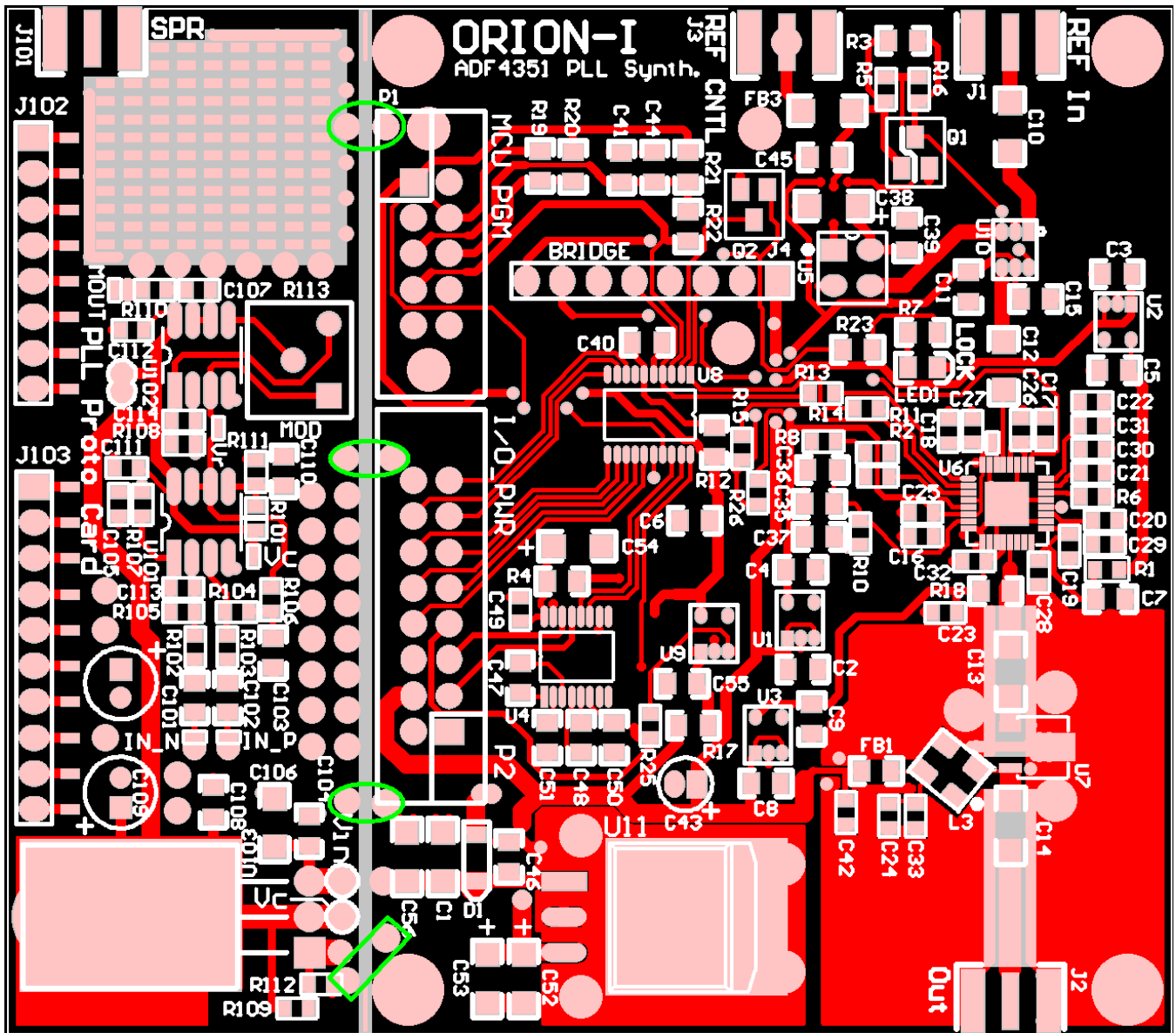

Figure 11. Prototype area ground points (at the **green** outline locations)

21 **Orion-I Operation**

Using an External Microcontroller

The Orion-I has provisions to allow an external MCU to directly control the PLL registers. This would allow a USB interface, or an ARM microcontroller to accomplish advanced control requirements. Such an interface could be part of an SDR system, or an instrument that requires sweep functionality that is beyond the capabilities of the simple 8051 that is installed at U8.

Exercising this capability requires that the 8051 processor (U8) on the Orion to be removed or disabled and the "Bridge" header connection used to provide the PLL control signals to the ADF4351. Removing U8 is the best option, but requires medium-level soldering skills to accomplish the task without damaging the PCB. Another option is to remove R12 and then lift the following U8 pins from their PCB solder pads: 1, 4, and 15. The RS232 converter IC (U4) must also be disabled by removing R4.

After the Orion is prepped, the "Bridge" header (an 8-pin, single-row, 0.1" pitch header footprint) can be used to connect an Arduino, Raspberry Pi, or similar processor to the Orion (see the table below). The software for the desired platform is beyond the scope of this document, but at minimum, it must accomplish the SPI functions to transfer the register data to the ADF4351 (using MOSI, SCK, and /CS_PLL). If desired, the LDETr signal can be read by the new processor to determine if the PLL is in lock. Refer to the ADF4351 datasheet for details regarding the SPI protocol required for the data transfer.

There are 4 mounting holes that surround the Bridge header. One is near J3, one is near U8 pin 1, and the remaining two are under the P1 connector (which may be removed since it is no longer needed) These holes are sized for 0-80 screws and may be used to secure a daughter board for the Bridge interface.

     Bridge Header Pinout:
     1: +5V (see note)
     2: GND
     3: MOSI (data signal to the ADF4351, sourced by the external processor)
     4: GND
     5: SCK (data clock, sourced by the external processor)
     6: GND
     7: /CS_PLL (PLL chip select, sourced by the external processor)
     8: LDETr (lock detect signal from the ADF4351, an input to the external processor)

Note: As mentioned earlier in this document, the +5V supply on the Orion is limited by the thermal solution employed by the user. If minimal heatsinking is provided, this pin should be limited to just a few mA of current if at all possible. Also, use power from this pin with great care as it is very easy to "pollute" the Orion 5V supply and thus increase its noise characteristics dramatically. Finally, it is possible to use this pin to supply power to the Orion which could simplify the installation. In this case, lift pin 3 of U11 and provide very clean 5V (±10%) power that can source at least 300 mA to the Bridge header. In this configuration, no other connections to the Orion would be required other than the RF output.

Appendix B
Schematic and BOM

Bill Of Materials

Designator	QTY	Part Type	Footprint	MFR P/N
C1, C38, C52, C53, C54, C56	6	10uF, 50V	1206	GRM31CR61H106MA12L
C2, C3, C4, C5, C6, C7, C8, C9, C44, C55	10	1.0uF, 50V	0805	UMK212BJ105KG-T
C10, C12, C13, C14	4	0.01uF, 50V, COG	1206	VJ1206A103JXATW1BC
C11, C40, C41, C46	4	0.1uF, 20V	0805	C0805C104K3RACTU
C15, C39, C45	3	0.01uF, 50V	0805	C0805C103K5RACTU
C16, C17, C18, C19, C20, C21, C22, C23, C24, C49	10	0.1uF, 35V	0603	0603DD104KAT2A
C25, C26, C27, C28, C29, C30, C31, C32, C33, (**C34**), C42	11	1000pF, 50V, COG	0603	GRM1885C1H102JA01D
C35	1	1500pF, 100V, COG	0805	08051A152JAT2A
C36	1	0.022uF, 25V, X7R	0805	C0805C223K3RACTU
C37	1	680pF, 50V, COG	0805	C0805C681J5GACTU
(**C43**)	1	100uF, 10V, ELYT	RB.05/.15	URS1A101MDD
C47, C48, C50, C51	4	0.33uF, 50V	0805	C0805C334K5RACTU
D1	1	Shottky, 2A, 60V	SOD123	NRVTS260ESFT1G
(**D2**)	1	BAS70-04	SOT23-A	BAS70-04
(**D3**)	1	TVS, UNI, 16V, 200W	DO219	SMF16A
FB1	1	FB, 300 ohm	0805	BLM21PG331SN1D
(**FB2**), FB3	2	FB, 600 ohm	1206	BLM31PG601SN1L
(**J1**), (**J2**)	2	CON, SMA, EDGE	CONN_SMA_edge	
(**J3**)	1	CON, MOLEX, 3P	CON3	22-23-2031
(**JP1**)	1	WIRE, 30AWG	N/A	Wire, 30AWG, 0.75"
(**L1**), (**L2**)	2	IND, 1uH	1206	LQM31PN1R0MC0L
L3	1	CHK, RF, uW	GU1604	TCCH-80+
LED1	1	LED, GRN	0805	APHCM2012CGCK-F01
(**P1**)	1	CON, 10P, Dual row	IDC10	5103309-1
(**P2**)	1	CON, 16P, Dual row	IDC16	D2516-6002-AR
(**P3**)	1	HSG, MOLEX, 3P	N/A	22-01-3037
(**P3-CONTACT**)	3	CONT, MOLEX	N/A	08-50-0114
Q1, Q2, (**Q3**)	3	TR, FET, N-CH	SOT-23	NDS355AN
ALT: Q1, Q2, (**Q3**)	-	TR, FET, N-CH	SOT-23	BSH103,215
R1, R2	2	0	0603	RC0603FR-070RL
R4	1	10	0805	RC0805JR-0710RL
R5, R16, (**R24**), R26	4	20.0K	0603	RC0603FR-0720KL
R6	1	4.70K	0603	RC0603FR-074K7L
R7, R21, R22, R23	4	1.00K	0805	RC0805FR-071KL
R8	1	100	0603	RC0603FR-07100RL
(**R9**)	1	100	0805	RC0805FR-07100RL
R10	1	820	0603	RC0603FR-07820RL
R11	1	332	0603	RC0603FR-07332RL

 Orion-I Operation

Designator	QTY	Part Type	Footprint	MFR P/N
R12	1	2.00	0805	RC0805JR-072RL
R13, R14, R15	3	1.00K	0603	RC0603FR-071KL
R17	1	5.1	0805	RC0805JR-075R1L
R18	1	49.9	0805	RC0805FR-0749R9L
R19	1	2.20K	0805	RC0805FR-072K2L
U1, U2, U3, U9	4	ADP150AUJZ-3.3-R7	SOT-23-5	ADP150AUJZ-3.3-R7
U4	1	IC, XCVR, RS232	TSSOP-16	MAX3232IPWR
U5	1	IC, OSC, 10.000M	SI510_4_3.2X5	ASFL1-10.000MHZ-EK-T
U5 (ALT)	-	IC, OSC, 10.000M	SI510_4_3.2X5	510CCA10M0000BAG (†)
U5 (ALT)	-	IC, OSC, 10.000M, TCXO	SI510_4_3.2X5	ASTX-H11-10.000MHZ-T
U6	1	ADF4351	32LFCSP_VQ	ADF4351BCPZ
U7	1	GVA-62+	DF782	GVA-62+
U8	1	IC, MCU, SiLABS	TSSOP-20	C8051F531-C-IT
U10	1	IC, SW, SPDT	SOT-23-6	SN74LVC1G3157DBVR
U11	1	IC, VREG, LDO, +5V	TO-263	LM2937ESX-5.0/NOPB
-	4	Standoff, 2-56, 0.5”	N/A	91780A027
-	8	Screws, 2-56, 0.25”	N/A	91772A055
-	1	CBL, RBBN, 16c, 5”	N/A	164-9008-E (conn) 3801/16 (100') (cable)
-	1	CON, DB-9, Female	N/A	L77SDE09S-ND
R3, R20, R25	3	DO NOT POPULATE	N/A	N/A

Note: (**BOLD**) *Designators identify components that are supplied un-attached with the Orion partial kit option. D1 is a top side component that might be supplied as a kit-part on some versions of the Orion partial kit.*

† - Order the SiLabs reference oscillator as follows:
  DigiKey: Order P/N 510CCA-BBAG and specify the frequency (10M0000) in the web order notes.
  Mouser: Order P/N 510CCA10M0000BAG (web order will say "non-stocked", but should still be available).

Note: The Orion schematic illustrates zero-value components for the prototype area circuits. These components are not installed and the values would be determined by the kit-builder based on the intended application.

Orion-I Operation

25

Prototype Area (optional)

Orion-I ADF-4351 PLL Synthesizer
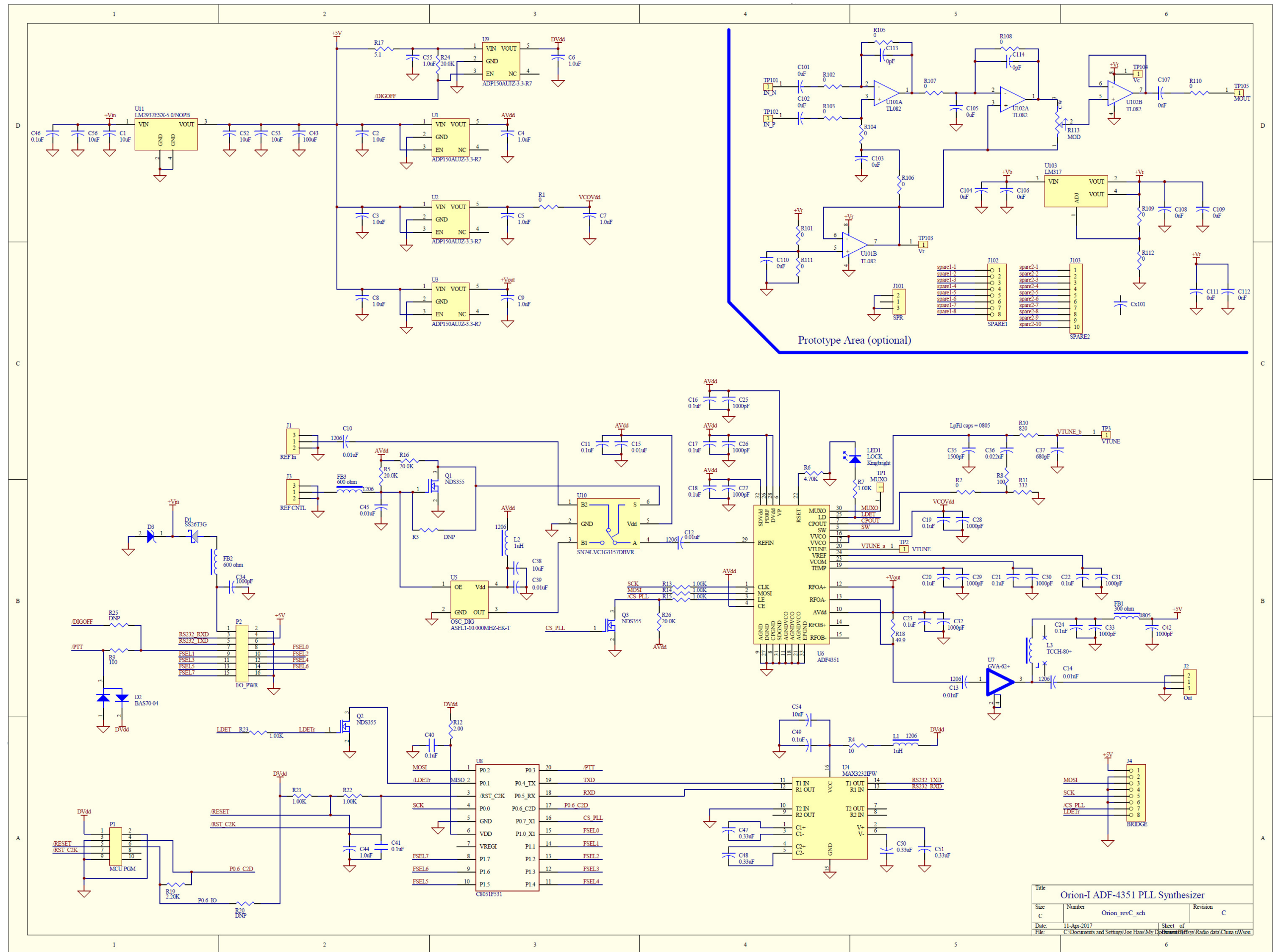
Title	Orion-I ADF-4351 PLL Synthesizer		
Size C	Number Orion_revC_sch		Revision C
Date: 11-Apr-2017		Sheet of	
File: C:\Documents and Settings\Joe Haas\My Documents\Biffsys Radio data\China uWsou			