VHF ApolLO LO

Background, Theory of Operation and Test Instructions

BACKGROUND

Knowing what frequency you are on has been the goal of many microwave operators. It makes finding other operators easier. On higher frequencies with weak signals, getting the antenna pointed in the right direction can be an issue and when combined with frequency uncertainty can make the search from someone even more difficult. On digital modes stability is not as much a preference or convenience as it is a necessity. We have all made contacts without the desired stability, but having the stability opens up new doors. The VHF ApolLO is a derivative of the apolLO I and apolLO-32 boards. The apolLO I board is a USB programmable LO (program and forget) that also has the capability to host an on-board TCXO. apolLO-32 is a simplification of the design the where the programming is done with jumpers or switches to preprogrammed frequencies. The VHF ApolLO is the same basic design as the apolLO-32, but can produce signals in the VHF range rather than the microwave range.

FEATURES

- Pre-programmed commonly-used VHF LO frequencies
- Dynamic optimization for temperature changes (automatically retunes PLL in the event of loss of lock)
- Requires and locks to external 10 MHz reference (or optional TCXO)
- Low power, consuming less than 2W
- Pre-drilled holes for mounting in a number of common transverter designs
- Connections for external lock indicator
- Excellent phase noise characteristics (100MHz: -87dBc/Hz @ 100Hz, -106dBc/Hz @ 1kHz, -110 dBc/Hz @ 10kHz)

- Superior stability limited only by quality of external reference which can be shared among several apolLO boards

THEORY OF OPERATION

The VHF ApolLO is a frequency synthesizer designed to operate in the 37-800 MHz range for use as a local oscillator (LO). Whereas the apolLO I's frequency is programmable via PC software and a USB port, VHF apolLO is programmed via a set of solder jumpers or switches. The PCB consists of four main sections. The power supply (section #1 in Figure 1) produces supply voltages required by the board.

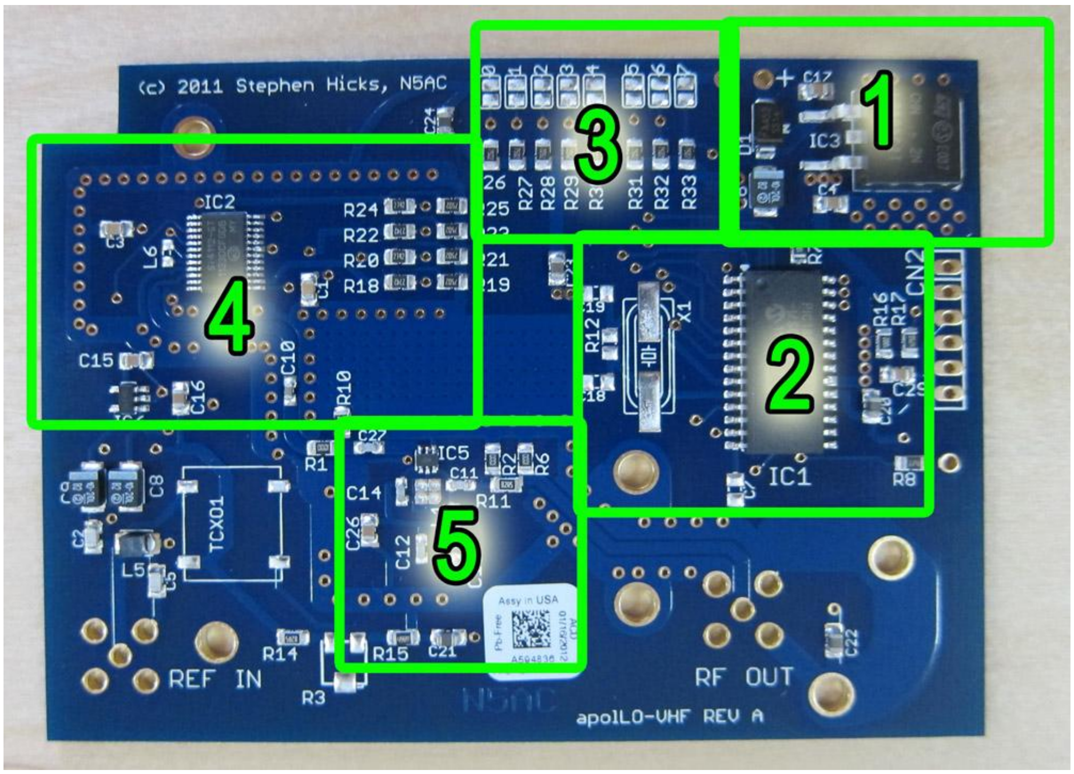


Figure 1, PCB Sections

The board will actually run off of up to 20V if necessary (more if higher voltage caps are used on the input of the voltage regulator – up to 35V).

The power supply produces two supply voltages, 4.5-5.0V used for the microprocessor and RF amplifier and 3.0V used for the synthesizer. Both supplies may also be used to power a TCXO.

The second major section of the board is the microprocessor (µP) (section #2 in Figure 1). The microprocessor's main purpose is to read jumpers and switches to determine which frequency the LO should use and to program the synthesizer with this information. The µP uses an internal clock for reduced noise on the board.

On power-up, the microprocessor reads the jumper or switch settings (see section #3 in ***Figure 1***) and uses the index (one of 256) to look up the operating parameters from the on-board EEPROM and writes this to the synthesizer. The synthesizer has no non-volatile memory for configurations itself.

The synthesizer needs a reference oscillator in order to function. For the VHF ApolLO, an external 10MHz reference is required. Because the synthesizer must know the frequency of the external reference in advance and 10MHz is the most commonly used reference frequency, all of the programming has been done exclusively for a 10MHz reference. Using a different frequency reference will result in the LO being off frequency. From this reference, the synthesizer produces the programmed output frequency. Internally, the synthesizer has a phase locked loop and the divider parameters for the loop can be programmed in the part after power-up. A block diagram of the Si41xx is shown in ***Figure 2*** (the VHF apolLO board actually uses the Si4112 part which does not include the RF synthesizers shown in the figure). The ÷R and ÷N parameters change based on the desired output frequency, phase detector update rate and the reference provided to the synthesizer. It is not necessary to understand how the synthesizer functions in detail to use the apolLO board, but many will find it interesting and will enjoy experimenting with the board to better understand how it operates.

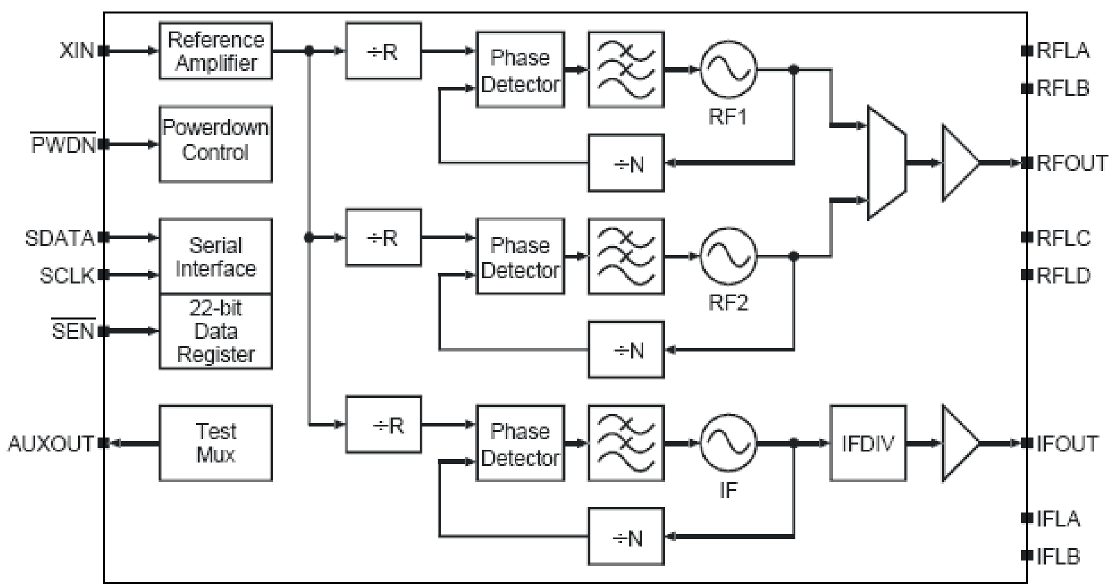


Figure 2, Si4133 Block Diagram

REFERENCE SELECTION

The reference input is provided with the large number of surplus high-stability 10 MHz references in mind. Because the N and R dividers are pre-programmed directly from the µP with a 10MHz reference in mind, only a 10 MHz reference can be used on the VHF ApolLO. If you would like to use a different frequency reference (2-26MHz), the apolLO I can accommodate other reference frequencies.

The synthesizer (section #4 in ***Figure 1***) uses an external inductor to set the operating range of the internal synthesizers. For this design, the objective was to fashion a PCB that would cover 70-400+MHz. This range encompasses the required starting LO frequencies for many transverter designs as can be seen in the table below as well as a number of weak signal frequencies and frequencies required for other transverters:

Band	IF	F_{APOLLO}	Multiplier	F_{LO}
144 MHz	28 MHz	116 MHz	1	116 MHz
432 MHz	28 MHz	101 MHz	4	404 MHz
222 MHz	144 MHz	78 MHz	1	78 MHz
432 MHz	50 MHz	382 MHz	1	382 MHz

Finally, the RF output of the Si41xx synthesizer can vary from -8dBm to +1dBm. Since most LO chains or mixers require a higher output level, an integrated RF amplifier is included on the board (section #5 in ***Figure 1***). The ABA-54563 is a 20dB gain block with a P1dB of 16dBm. Sufficient padding is provided to isolate the synthesizer from the PA and the PA from the outside world (transverter). The output of the board has been pre-adjusted to +5dBm ±2dB.

The board is designed to be a form-fit replacement for several existing transverter LOs. All voltage in, RF out and reference-in are designed to be accessed from either the top or bottom of the board depending on how the board is mounted. It is expected that most will use the apolLO with an external reference connected to a BNC placed on the rear of the transverter – often an extra hole is already available where the split IF port would go. If you are using common IF in a DEMI transverter, this extra hole will often be open.

PROGRAMMING YOUR VHF ApolLO

The VHF ApolLO can be "programmed" using either solder jumpers, switches or both. In general, solder jumpers on the board shown as section #3 in ***Figure 1*** are used to program the frequency as shown in JUMPER SETTINGS. Once the jumper is soldered, the LO will always start on the programmed frequency. The processor continually scans the jumpers so that a transverter that may use more than one frequency can be built that uses switches to change between different LO frequencies in real time.

It is generally not necessary to bridge the jumper with a wire—a blob of solder will bridge the connection if you allow the soldering iron to touch both pads of the jumper at the same time.

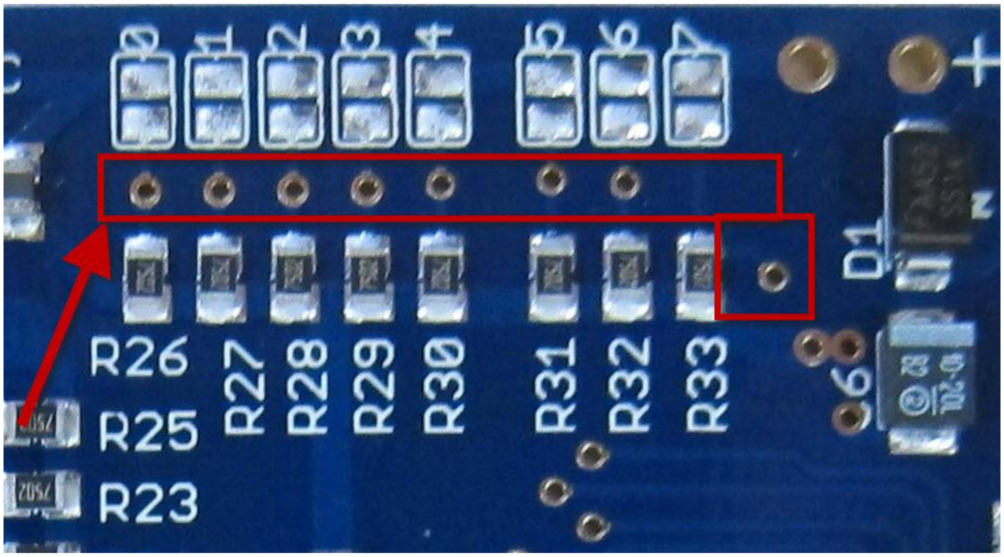


Figure 3, Switch hole locations

There is also a set of holes in the board that parallel the jumpers. In other words, they perform the same function as the jumpers. These can be used to dynamically change the LO frequency. There are a couple of reasons for doing this. First, if you operate in different band-segments, the LO can switch between segments so that a separate transverter or tuning of the IF to the new band segment is not required. Jumper positions were selected to make this an easy process also. The hole locations for switches are highlighted in ***Figure 3***.

UNDERSTANDING THE SYNTHESIZER AND LOCK

The VHF ApolLO is preprogrammed to lock on to each of the selectable frequencies. Situations could occur that would cause a loss-of-lock, however. The included LED should be placed on the front panel of the transverter and wired to the LOCK LED hole in the PCB indicated in ***Figure 4***. This point should be connected to the long lead (anode) of the LED and the short lead (cathode) should be connected to ground.

This LED can be used as a diagnostic aid to determine if any lock problems occur. The LED indication is derived from the LDETB output of the on-board synthesizer. Under normal conditions, the blue LED will light solid indicating a good lock. If, however, you are on the edge of the synthesizer range or there is another problem, the synthesizer may not be able to lock. Unfortunately, this is not always a "black and white" situation. Sometimes, the synthesizer will gradually lose lock. In this situation, the Blue LED would normally begin to very slowly dim in intensity as the lock weakened. Because we felt that this was an unacceptable way to report a lock failure (we can't seem to make our eyes detect a 1% loss of light in an LED), we have devised a better method for providing lock information. It works like this:

The apolLO microprocessor samples the LDETB (lock detect) line of the synthesizer about 10,000 times a second. After 1000 samples, the software examines the number of times that a lock was detected. If there was a lock detect signal present in every sample (100%), then the lock detect LED is lit solid and the Setup Utility reports the message "LOCKED."

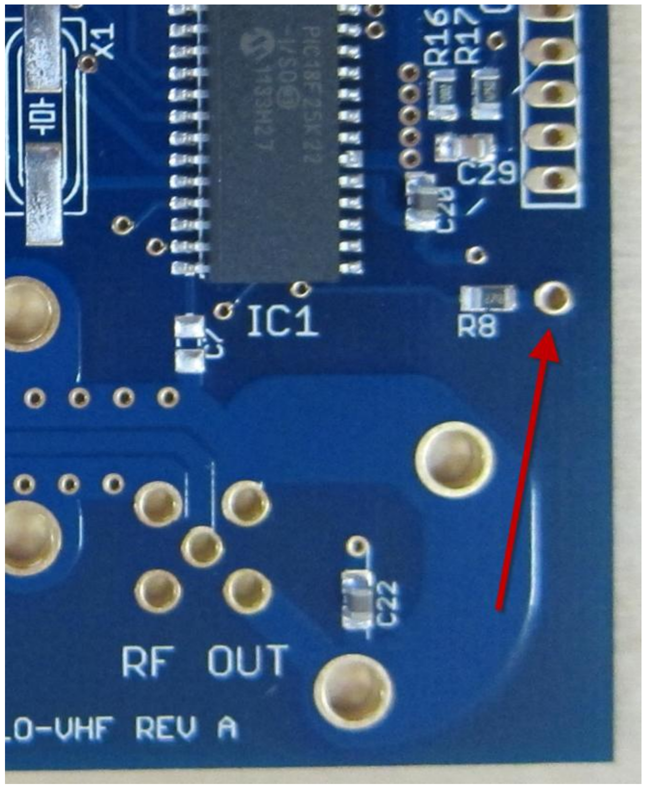


Figure 4, Lock LED indicator hole

If, on the other hand, it detects a 0-10% failure of lock detect, "Weak Lock" is reported and the LED will blink fast. In this situation, we can guarantee that the resulting signal is not pure carrier. You do not want to run the synthesizer in this mode, but we have setup the board to give you an indication of the type of problem encountered for aid in setup and troubleshooting. When lock is lost, the PLL will be operating open loop until lock is reestablished and the resulting carrier will be wandering around. For a weak lock, this can result is significant phase noise or even choppy reception as the LO wanders around. Again, we recommend not using the LO in this situation. If you do, your output will vary depending on the character of the lock, but in most situations your signal will be spread over a range of output frequencies and will be very broad-banded. You generally will have some output signal on the desired carrier frequency, but you will also be transmitting on many other frequencies in all likelihood.

The moment that the microprocessor detects a lock failure, it first tries to reestablish lock by forcing the synthesizer to implement its internal auto-tune software. This software attempts to compensate for inductor values on the part, temperature variations and the like to get the oscillator back on channel. If a temperature drift is the cause of the lock loss, initially the auto-tune algorithm in the synthesizer will be successful. This is designed to automatically compensate for changes in temperature of the LO and the like. If you are watching the LO when this happens, the software forces the lock LED to go dark for approximately 20ms which appears as a short off blink. We tested this software in the lab by rapidly cooling and heating the PCB and watching a series of retunes occur successfully. In the field, these retunes generally would only occur with large temperature swings (> 30º C) which might happen over a series of hours in a rover or on a tower.

If the lock detect is lost for 10%-90% of the time, a "poor lock" is reported. A spectrum plot of the carrier during an example period is shown in ***Figure 5*** for information—again you would not want to use the LO in this situation and with the pre-programmed values, the synthesizer should never end up in this position.

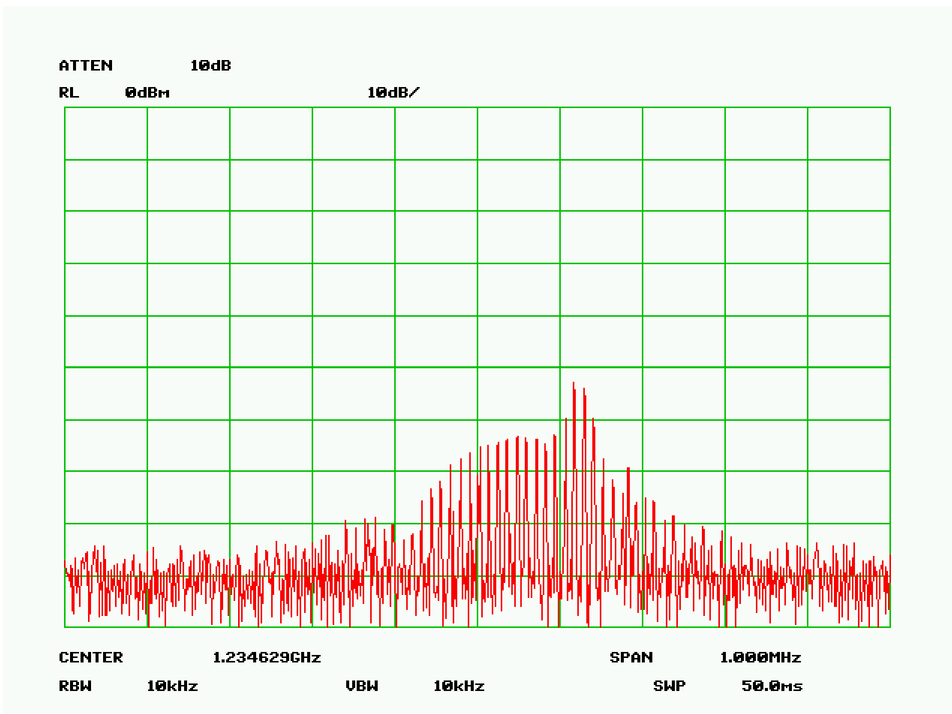


Figure 5, Example Poor Lock Plot

A lock detect percentage of <10% is reported as UNLOCKED and you would not want to use the LO in this situation either.

If you encounter a lock issues with the VHF apolLO, there are a few things to try. First, verify that your 10 MHz reference is successfully making it to the synthesizer board and has a sufficient level. Without the reference, there is nothing to lock to and you will always get a lock failure.

The next issue to consider is use of the wrong tuning inductor. The board ships with the inductor indicated on the front cover sheet. The table at the back of this document shows a recommended and alternate inductor to use for the frequency you have chosen. If you have the wrong inductor, the VHF ApolLO may lock in ambient temperature conditions, but then may fail to lock in temperature extremes when roving, for example.

It is worth mentioning that the range covered by the LO is, in fact, beyond the specifications of the synthesizer. Because we were able to successfully obtain lock with a number of different parts outside of the normal range, the circuit was built around the chip's actual capabilities. The chip manufacturer does not guarantee operation outside of the specifications published so it is possible to get a part that is outside of the typical operating characteristics and will not lock where you would like. In the event that this occurs, we will gladly service the board and do what is necessary to get the board operating where you need it.

In general, movement of about 1mm will move the center frequency of the VCO by 6MHz or so and the base oscillator frequency. You may move the inductors a small amount to try to re-achieve lock if a particular frequency is giving you trouble. Moving the inductor towards the synthesizer raises the frequency and moving it away from the synthesizer lowers the frequency.

INSTALLING THE VHF ApolLO

Separate detailed instructions for installing the LO in a DEMI transverter are provided by DEMI. Briefly, the steps are:

- ❒ If you have an existing LO, remove it by unscrewing screws holding it to the transverter and unsolder the LO coax from the board and the power lead.
- ❒ The +9V line coming from the transverter control board should be soldered in the hole on the apolLO board marked +6-12V. In actuality, the board can handle up to 20VDC. Ground return is through the screws in the lid of the transverter and the coax although you can run a separate ground to the ground hole next to the +6-12V hole if you like.
- ❒ Connect the LO coax in the hole marked RF output on the apolLO. Any of the adjacent ground holes around the output hole can be used for the shield of the coax.
- ❒ Install the BNC in the rear panel in the available hole or drill a suitable hole and connect the reference input pad on the board to the BNC via a small jumper of coax.

When transverter power is turned on the blue LED (locked) should be lit solid if the LO is programmed and locked on to the specified frequency.

If you would like to put an external lock LED on your transverter, two holes marked LOCK can be run out to an external LED. Depending on your LED selection, you may need to remove the existing LED on the board to ensure proper current/voltage makes it to your LED.

PHASE NOISE CHARACTERISTICS

The VHF apolLO's phase noise characteristics are a function of two key subsystems: the reference oscillator used by the synthesizer and the synthesizer itself. The apolLO has been tested with several references to date including a Z3801 GPS locked reference, an Isotemp OCXO (model 134) and the Datum OCXO and various signal generators. From a phase noise perspective, the crystal oscillators have better phase noise than the signal generators that employ synthesizers.

Figure 6 shows a phase noise plot using the Z3801 when the synthesizer is tuned to 116 MHz. The readings from this plot are as follows:

10 Hz	-82 dBc/Hz
100 Hz	-90 dBc/Hz
1 kHz	-108 dBc/Hz
10 kHz	-112 dBc/Hz
100 kHz	-120 dBc/Hz
1 MHz	-130 dBc/Hz

The phase noise at 1 MHz is slightly higher due to the phase detector spurs at this frequency.

Note that the test setup used to measure the VHF ApolLO was an Agilent 8565E that has a noise floor that is above the VHF ApolLO as seen in ***Figure 7*** so the measurement shows only that the oscillator phase noise is below that of the analyzer.

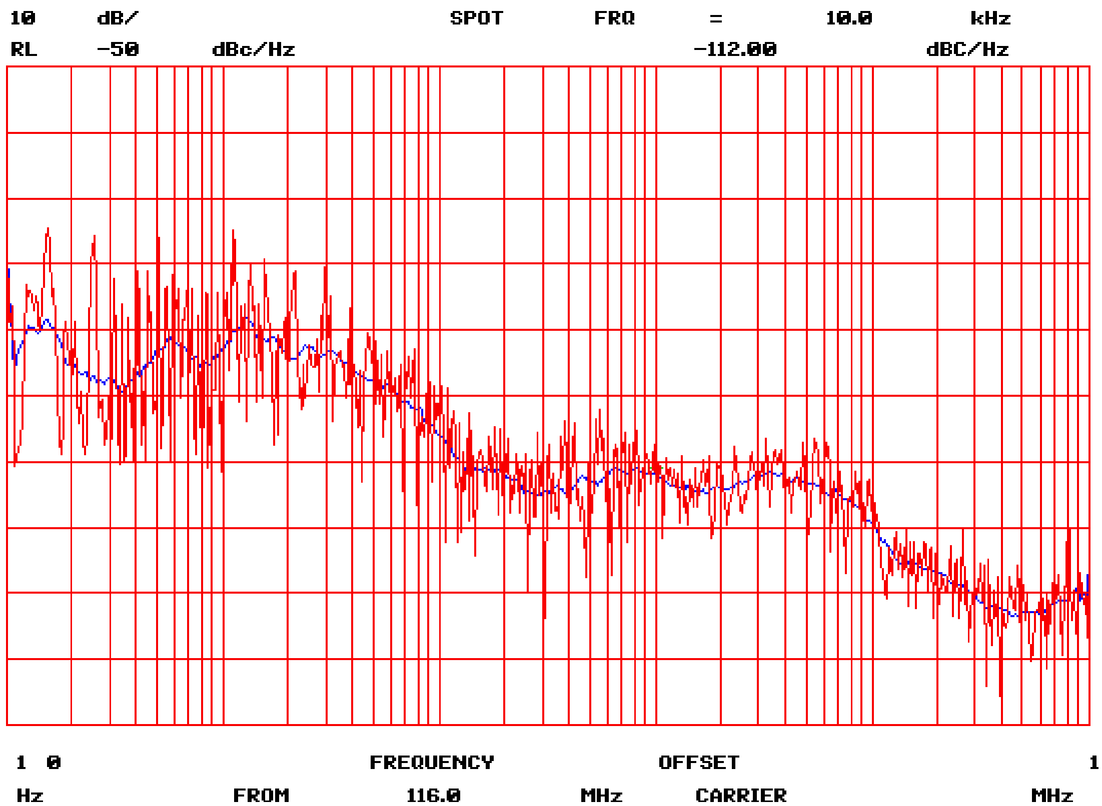
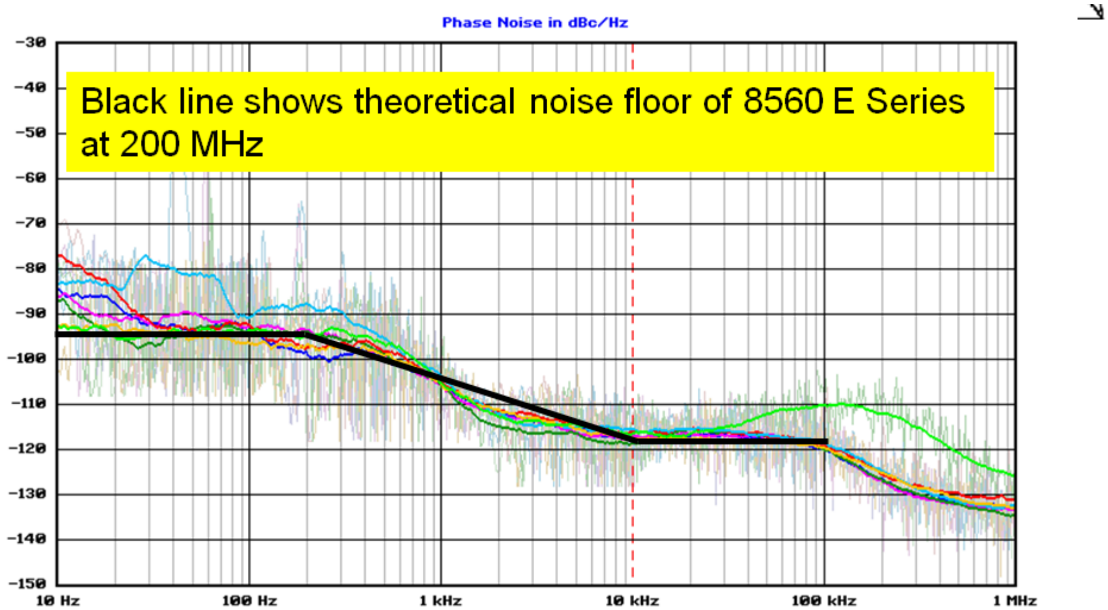


Figure 6, Z3801 and distribution box @ +6dBm driving VHF ApolLO, 116 MHz, 1MHz phase detector update



Trace	Carrier Hz	Carrier dBm	dBc/Hz at 10000 Hz	RF Atten dB	Instrument
96MHz_Clock	95 999 950	12.00	-117.4	20	HP8565E
80MHz_Clock	80 001 320	13.00	-116.7	20	HP8565E
50MHz_Clock	50 000 050	9.67	-118.4	10	HP8565E
23.4MHz_Clock	23 408 000	5.83	-116.0	10	HP8565E
99.6MHz KD6OZH	99 600 600	9.83	-115.4	10	HP8565E
10MHz_Isotemp_MSA1104	10 000 000	16.00	-117.3	20	HP8565E
10MHz_Isotemp_MSA1104_X10Mult	99 999 980	5.00	-116.1	10	HP8565E

Figure 7, Noise floor of Agilent 8565E used in testing of VHF ApolLO

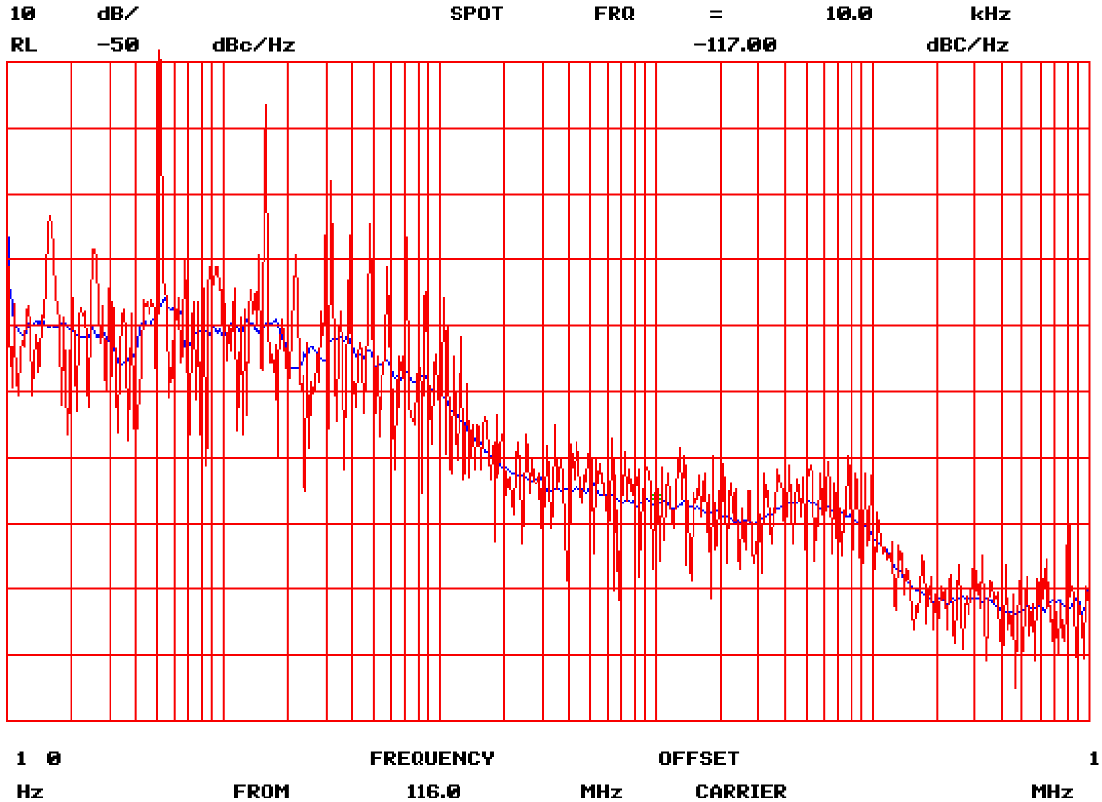


Figure 8, Datum OCXO and distribution box @ +6dBm driving VHF ApolLO, 116 MHz, 1MHz phase detector update

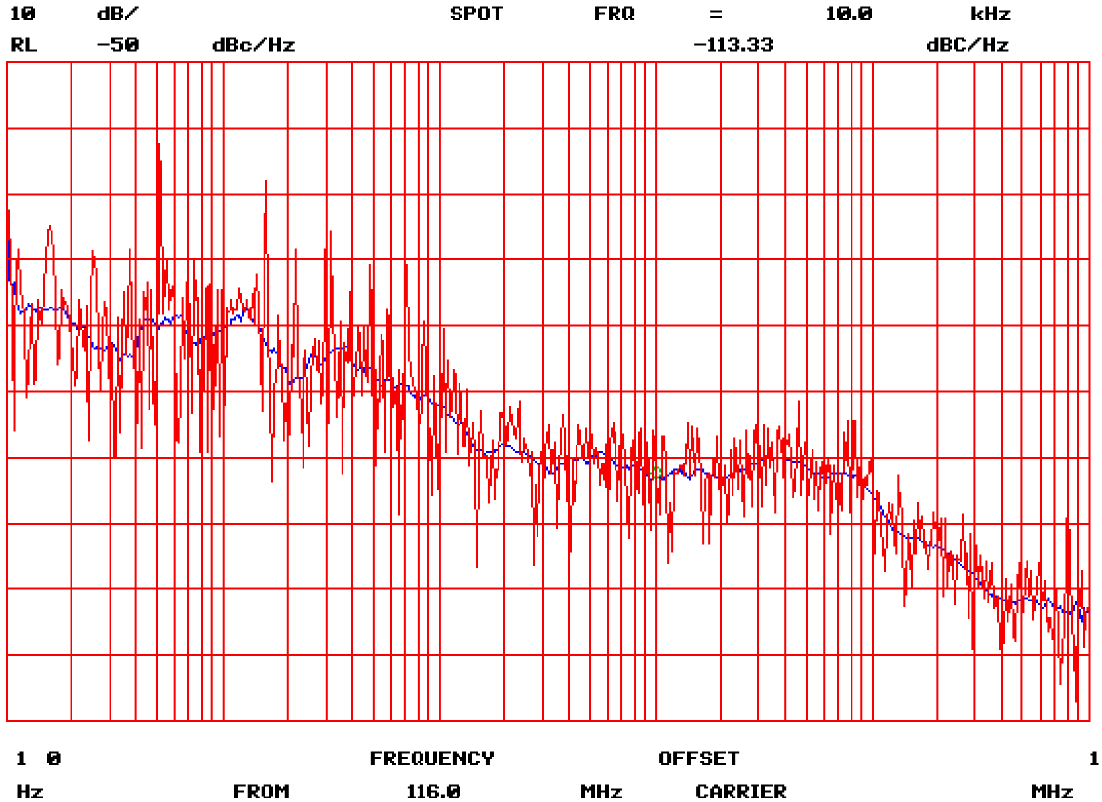
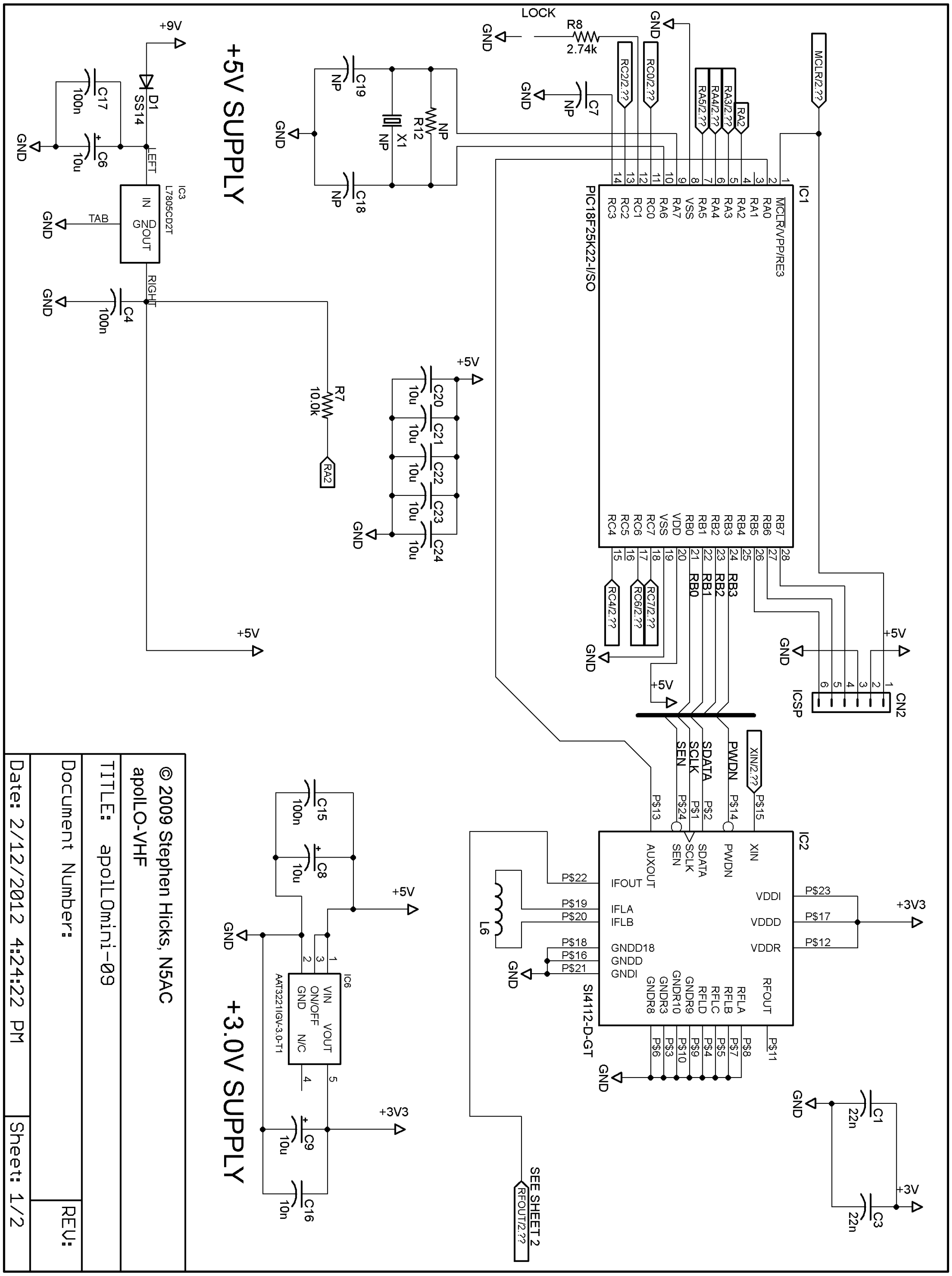


Figure 9, Isotemp OCXO and distribution box @ +3dBm driving VHF ApolLO, 116 MHz, 1MHz phase detector update

Other than the design of the synthesizer, the other key component in phase noise is the update rate of the phase detector. The higher the update rate, the less close-in phase noise is present. For most amateur applications, it will be easy to use a 1 MHz phase update rate, but for some, a lower value will have to be used since the LO frequency is not on an even 1MHz boundary. We have calculated the phase detector update rate and the predicted phase noise for each frequency. This is shown in the strap table at the end of this document.

SCHEMATICS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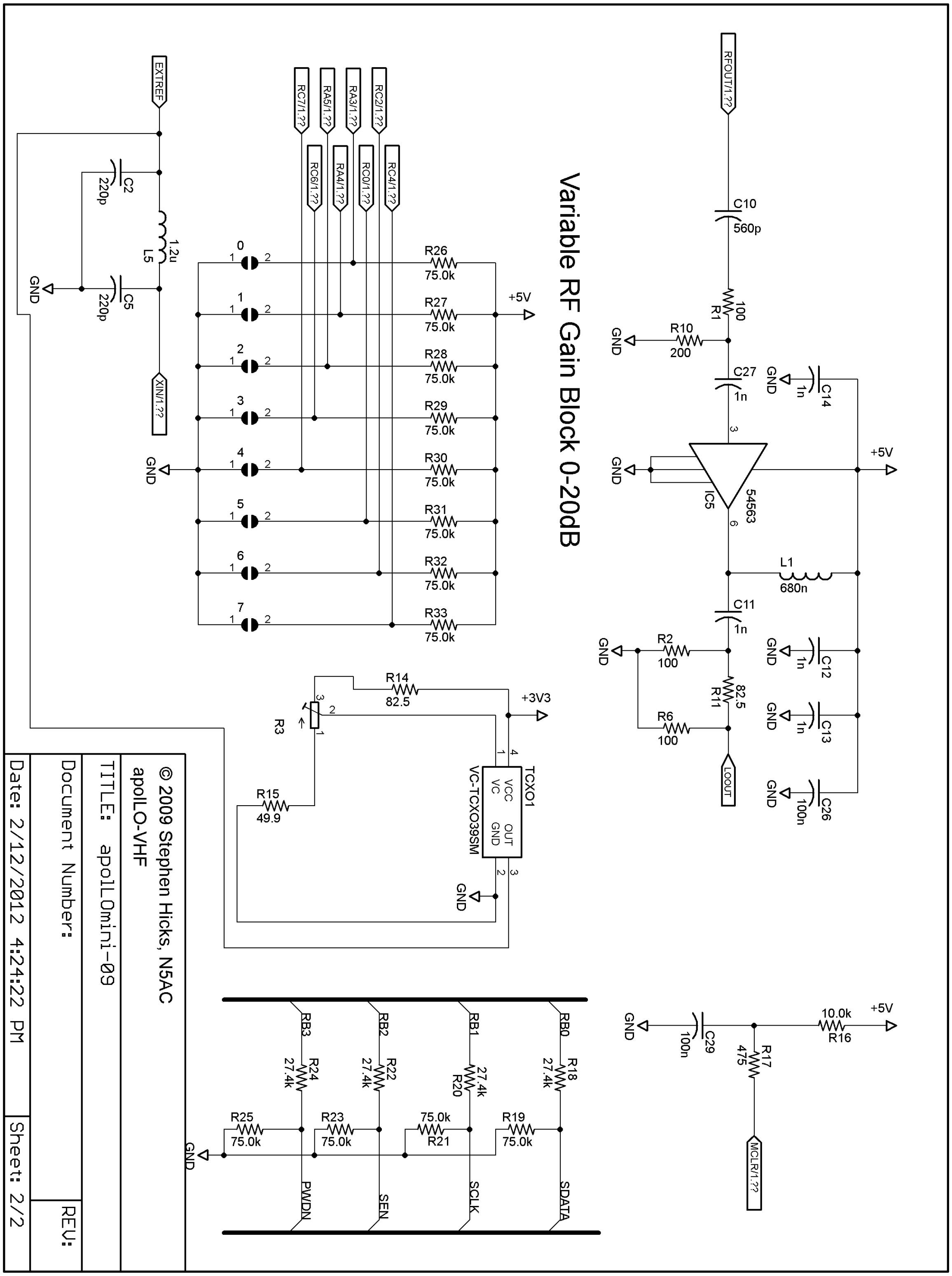
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R10 200
C27 1n
C14 1n
IC5 54563
L1 680n
C11 1n
R2 100
R11 82.5
R6 100
C12 1n
C13 1n
C26 100n
LOOUT
+5V
GND
EXTREF
C2 220p
L5 1.2u
C5 220p
XIN/1.??
RC7/1.?? RA5/1.?? RA3/1.?? RC2/1.??
RC6/1.?? RA4/1.?? RC0/1.?? RC4/1.??
R26 75.0k
R27 75.0k
R28 75.0k
R29 75.0k
R30 75.0k
R31 75.0k
R32 75.0k
R33 75.0k
R14 82.5
+3V3
R3
R15 49.9
TCXO1 VC-TCXO39SM
VCC VC OUT GND
C29 100n
R16 10.0k
R17 475
MCLR/1.??
RB3 RB2 RB1 RB0
R24 27.4k
R22 27.4k
R20 27.4k
R18 27.4k
R25 75.0k
R23 75.0k
R21 75.0k
R19 75.0k
PWDN SEN SCLK SDATA

JUMPER SETTINGS

VHF ApolLO									STRAPS																	
Band	RF	IF	MULT	Synth	Freq	Ind	Alt Ind	REV	7	6	5	4	3	2	1	0	Case	R	N	X	Fund	Fcalc	PD	10Hz	1kHz
REF				IF	100	2.2	1.8	A									0	800	10	3	800.	100	1,000	-88	-100
2M	144	28	1	IF	116	1.8	1	A								X	1	928	10	3	928.	116	1,000	-88	-100
70CM	432	28	4	IF	101	2.2	1.8	A							X		2	808	10	3	808.	101	1,000	-88	-100
1.25CM	220	28	2	IF	96	2.2	1.8	A							X	X	3	768	10	3	768.	96	1,000	-88	-100
1.25CM	222	28	2	IF	97	2.2	1.8	A						X			4	776	10	3	776.	97	1,000	-88	-100
2M	144	29	1	IF	115	1.8	2.2	A						X		X	5	920	10	3	920.	115	1,000	-88	-100
2M	144	27	1	IF	117	1.8	1	A						X	X		6	936	10	3	936.	117	1,000	-88	-100
2M	144	26	1	IF	118	1.8	1	A						X	X	X	7	944	10	3	944.	118	1,000	-88	-100
2M	144	25	1	IF	119	1	1.8	A					X				8	952	10	3	952.	119	1,000	-88	-100
2M	144	24	1	IF	120	1	1.8	A					X			X	9	960	10	3	960.	120	1,000	-88	-100
2M	144	28.5	1	IF	115.5	1.8	2.2	A					X		X		10	924	10	3	924.	115.5	1,000	-88	-100
2M	144	29.5	1	IF	114.5	1.8	2.2	A					X		X	X	11	916	10	3	916.	114.5	1,000	-88	-100
1.25M	222	26	2	IF	98	2.2	1.8	A					X	X			12	784	10	3	784.	98	1,000	-88	-100
1.25M	222	27	2	IF	97.5	2.2	1.8	A					X	X		X	13	780	10	3	780.	97.5	1,000	-88	-100
1.25M	222	29	2	IF	96.5	2.2	1.8	A					X	X	X		14	772	10	3	772.	96.5	1,000	-88	-100
1.25M	222	28.5	2	IF	96.75	2.2	1.8	A					X	X	X	X	15	774	10	3	774.	96.75	1,000	-88	-100
1.25M	222	29.5	2	IF	96.25	2.2	1.8	A				X					16	770	10	3	770.	96.25	1,000	-88	-100
1.25M	220	29	2	IF	95.5	2.2	1.8	A				X				X	17	764	10	3	764.	95.5	1,000	-88	-100
1.25M	220	30	2	IF	95	2.2	1.8	A				X			X		18	760	10	3	760.	95	1,000	-88	-100
70CM	432	29	4	IF	100.75	2.2	1.8	A				X			X	X	19	806	10	3	806.	100.75	1,000	-88	-100
70CM	432	26	4	IF	101.5	2.2	1.8	A				X		X			20	812	10	3	812.	101.5	1,000	-88	-100
70CM	432	27	4	IF	101.25	2.2	1.8	A				X		X		X	21	810	10	3	810.	101.25	1,000	-88	-100
70CM	432	28.5	4	IF	100.875	2.2	1.8	A				X		X	X		22	807	10	3	807.	100.875	1,000	-88	-100
70CM	432	29.5	4	IF	100.625	2.2	1.8	A				X		X	X	X	23	805	10	3	805.	100.625	1,000	-88	-100
1.25M	22	29.5	2	IF	95.25	2.2	1.8	A				X	X				24	762	10	3	762.	95.25	1,000	-88	-100
70CM	435	28	4	IF	101.75	2.2	1.8	A				X	X			X	25	814	10	3	814.	101.75	1,000	-88	-100
70CM	435	27	4	IF	102	2.2	1.8	A				X	X		X		26	816	10	3	816.	102	1,000	-88	-100
70CM	435	26	4	IF	102.25	2.2	1.8	A				X	X		X	X	27	818	10	3	818.	102.25	1,000	-88	-100
1.25M	220	50	1	IF	170	4.7	8.2	A				X	X	X			28	680	10	2	680.	170	1,000	-82	-94
1.25M	222	51	1	IF	171	4.7	8.2	A				X	X	X		X	29	684	10	2	684.	171	1,000	-82	-94
1.25M	222	50	1	IF	172	4.7	8.2	A				X	X	X	X		30	688	10	2	688.	172	1,000	-82	-94
1.25M	220	30	1	IF	190	2.2	4.7	A				X	X	X	X	X	31	760	10	2	760.	190	1,000	-82	-94
1.25M	220	29	1	IF	191	2.2	4.7	A			X						32	764	10	2	764.	191	1,000	-82	-94

VHF ApolLO									STRAPS																
Band	RF	IF	MULT	Synth	Freq	Ind	Alt Ind	REV	7	6	5	4	3	2	1	0	Case	R	N	X	Fund	Fcalc	PD	10Hz	1kHz
1.25M	220	29	1	IF	192	2.2	4.7	A			X					X	33	768	10	2	768.	192	1,000	-82	-94
1.25M	222	29.5	1	IF	192.5	2.2	4.7	A			X				X		34	770	10	2	770.	192.5	1,000	-82	-94
1.25M	222	29	1	IF	193	2.2	4.7	A			X				X	X	35	772	10	2	772.	193	1,000	-82	-94
1.25M	222	28.5	1	IF	193.5	2.2	4.7	A			X			X			36	774	10	2	774.	193.5	1,000	-82	-94
1.25M	222	28	1	IF	194	2.2	4.7	A			X			X		X	37	776	10	2	776.	194	1,000	-82	-94
1.25M	222	27	1	IF	195	2.2	4.7	A			X			X	X		38	780	10	2	780.	195	1,000	-82	-94
1.25M	222	26	1	IF	196	2.2	4.7	A			X			X	X	X	39	784	10	2	784.	196	1,000	-82	-94
70CM	432	51	1	IF	381	2.2	4.7	A			X		X				40	762	10	1	762.	381	1,000	-76	-88
70CM	432	50	1	IF	382	2.2	4.7	A			X		X			X	41	764	10	1	764.	382	1,000	-76	-88
70CM	435	52	1	IF	383	2.2	4.7	A			X		X		X		42	766	10	1	766.	383	1,000	-76	-88
70CM	435	51	1	IF	384	2.2	4.7	A			X		X		X	X	43	768	10	1	768.	384	1,000	-76	-88
70CM	435	50	1	IF	385	2.2	4.7	A			X		X	X			44	770	10	1	770.	385	1,000	-76	-88
70CM	432	30	1	IF	402	2.2	4.7	A			X		X	X		X	45	804	10	1	804.	402	1,000	-76	-88
70CM	432	29.5	1	IF	402.5	2.2	4.7	A			X		X	X	X		46	805	10	1	805.	402.5	1,000	-76	-88
70CM	432	29	1	IF	403	2.2	4.7	A			X		X	X	X	X	47	806	10	1	806.	403	1,000	-76	-88
70CM	432	28.5	1	IF	403.5	2.2	4.7	A			X	X					48	807	10	1	807.	403.5	1,000	-76	-88
70CM	432	28	1	IF	404	2.2	4.7	A			X	X				X	49	808	10	1	808.	404	1,000	-76	-88
70CM	432	27	1	IF	405	2.2	4.7	A			X	X			X		50	810	10	1	810.	405	1,000	-76	-88
70CM	435	29	1	IF	406	2.2	4.7	A			X	X			X	X	51	812	10	1	812.	406	1,000	-76	-88
70CM	435	28	1	IF	407	2.2	4.7	A			X	X		X			52	814	10	1	814.	407	1,000	-76	-88
70CM	435	27	1	IF	408	2.2	4.7	A			X	X		X		X	53	816	10	1	816.	408	1,000	-76	-88
70CM	435	26	1	IF	409	2.2	4.7	A			X	X		X	X		54	818	10	1	818.	409	1,000	-76	-88
1.25M	222	145	1	IF	77	8.2	4.7	A			X	X		X	X	X	55	616	10	3	616.	77	1,000	-88	-100
1.25M	222	144	1	IF	78	8.2	4.7	A			X	X	X				56	624	10	3	624.	78	1,000	-88	-100
1.25M	220.1	WSS	3	IF	73.36667	8.2	—	A	X	X	X	X				X	241	2201	75	2	293.47	73.36667	133	-68	-88
1.25CM	222.1	WSS	3	IF	74.03333	8.2	—	A	X	X	X	X			X		242	2221	75	2	296.13	74.03333	133	-68	-88
70CM	432.1	WSS	6	IF	72.01667	8.2	—	A	X	X	X	X			X	X	243	4321	150	2	288.07	72.01667	67	-63	-86
70CM	435.1	WSS	6	IF	72.51667	8.2	—	A	X	X	X	X		X			244	4351	150	2	290.07	72.51667	67	-63	-86
33CM	903.1	WSS	12	IF	75.25833	8.2	—	A	X	X	X	X		X		X	245	9031	300	2	301.03	75.25833	33	-58	-84
33CM	902.1	WSS	12	IF	75.175	8.2	—	A	X	X	X	X		X	X		246	9021	300	2	300.7	75.175	33	-58	-84
23CM	1296.1	WSS	18	IF	72.00556	8.2	—	A	X	X	X	X	X				248	12961	450	2	288.02	72.00556	22	-56	-82
2M	144.1	WSS	2	IF	72.05	8.2	—	A	X	X	X	X	X			X	249	4323	150	2	288.2	72.05	67	-63	-86
2M	144.2	WSS	2	IF	72.1	8.2	—	A	X	X	X	X	X		X		250	4326	150	2	288.4	72.1	67	-63	-86
4M	70.1	WSS	1	IF	70.1	8.2	—	A	X	X	X	X	X	X			252	1402	25	3	560.8	70.1	400	-82	-97

FINAL COMMENTS

I hope you enjoy your VHF ApolLO board and I hope it serves your LO needs. If you should have any comments about the board, any recommendations or comments about the documentation, I would be interested in hearing them. Please send your comments to apollo@n5ac.com

Thanks & 73,
Steve, N5AC