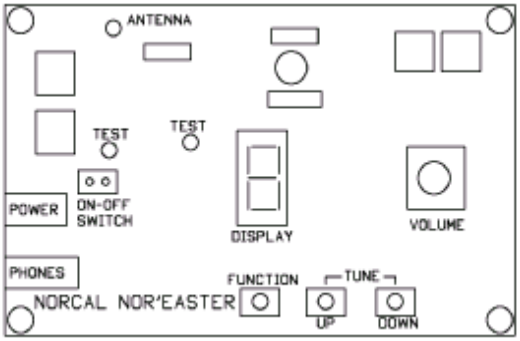
THE NORCAL NOR'EASTER

A 5.2 to 17 MHz Short Wave AM Receiver
Featuring digital PLL tuning
Custom designed for NorCal by Steven Weber KD1JV



AUDIO

The audio jack is set up for stereo headphones. There is enough drive for a small 8Ω speaker if you wish. You will need to wire it to a stereo plug, using the tip and ground ring. The receiver is very quiet until you are tuned to or near a station. Don't leave the volume turned up too high when your tuning around, especially with headphones on, or you might blow your ears off!

POWER SUPPLY:

The Nor'Easter is nominally powered with a 7.5 volt source, and draws about 25 ma. The receiver will work with voltages between 6 and 9 volts. Power is inputted using a 7 mm coaxial power jack and plug.

ANTENNA

The Nor'Easter is designed to be used with a short antenna, such as a three foot piece of wire. A long wire antenna will most likely overload the input.

OPERATION

When powered up for the first time, the receiver is programmed to load the low end of the tuning range, 5.200 MHz. The single digit LED frequency display will sequence out the operating frequency, MHz digit first, leading zero suppressed, and then go blank to conserve power. If a frequency is programmed into memory location [0], the receiver will power up on that frequency.

TUNING

The receiver is tuned by using the up / down tuning buttons. These are best activated by rocking them side to side, rather than pushing directly down on them.

The receiver tunes in 5 KHz steps, each time the button is “clicked”. If one of the buttons is held closed for longer than one second, an auto tune mode is enabled, which automatically increments the frequency at fairly fast rate. If the auto tune mode has been enabled, 1.5 seconds after the tuning button is subsequently released, the frequency display will automatically be activated. The delay allows you time to single step the tuning buttons to fine tune in a station you might have gone past, without first having to wait for the display to finish sequencing.

TUNING LIMITS:

When the receiver is tuned to it’s band limits, an “H” will be displayed on the LED at the upper limit, 17.000 MHz. An “L” will be displayed at the lower limit, 5.200 MHz.

FUNCTIONS:

The FUNCTION button controls four receiver functions.

1. Activate the frequency readout
2. Select preprogrammed short wave bands
3. Select user programmed frequencies
4. Store a frequency into memory.

The various functions are selected by holding down the function button for various lengths of time. A momentary click of the function button will activate the frequency readout. Holding the function button closed for a longer than one second will start to sequence through the remaining options, in one (1) second intervals. The current function is indicated on the display and that function is activated by releasing the function button while that option is being displayed. Scrolling past the last function will exit the function select mode.

Functions are indicated by the following letters on the display:

“b” Band selection
“r” recall a memory
“S” store into a memory

Once a function is selected by releasing the button, the selected function indication will remain on the display until the Tune Up or Tune Down buttons are used, or the function mode can be escaped with no action taken by pushing the function button again.

BAND SELECTION:

Six preprogrammed short wave frequencies are available for quickly getting to various locations in the tuning range of the receiver. These are:

(0) - 6.000 MHz, **(1)** - 7.500 MHz **(2)**- 9.5000 MHz **(3)** -11.500 MHz **(4)**-13.500 MHz **(5)**- 15.500 MHz

Locations 6-9 are not used and pushing the function button while one of these locations are selected will return the receiver back to the frequency where it was tuned. If one the 0-5 locations is selected when the Function button is pushed, the receiver will tune to that frequency and the frequency display will automatically activate.

In addition the locations 0-9, there is also a blank location indicated by a dash [-] on the display. While the dash is being displayed, pushing the Function button will escape the function and return the receiver to normal operation.

MEMORY RECALL FUNCTION:

Up to ten of your favorite short wave stations may be stored into memory. If a frequency is stored into memory location “0”, this is used as the default power on frequency of the receiver. Operation of the Memory recall function works just like the band selection mode. Use the Tune up or Tune Down button to select one of the ten locations, 0-9, then use the function button to activate. The display will automatically readout the new frequency. If the location is blank, an “E” for empty will be displayed for one second.

MEMORY STORE FUNCTION:

Once again, the memory store function works just like the band select and memory recall function. Use the Tune Up and Tune Down buttons to select a location, then push the Function button to store the frequency the receiver is currently tuned to into that location. The display will simply blank and the receiver returned to normal operation.

CONSTRUCTION:

WORKING WITH SURFACE MOUNTED PARTS:

In addition to your regular set of tools, you will need a pair of tweezers and a magnifying glass. You should also have a soldering iron in the 25-35 watt range, with a small tip. A 1/16” or 1/8” flat blade tip or a pointy conical tip is recommended. It is also recommended that you get a spool of 0.015” dia. Silver bearing solder. You can find this at Radio Shack, part number 64-035. You will find this works much better than “regular” solder for SMT parts. A spool of solder wick is also good to have handy.

SMT parts are soldered to the board by first lightly tinning one pad for the part to be placed. In the case of a transistor, this would be the collector lead, the side with only one lead. In the case of an IC, it would be one of the corner pin pads. Now pick up the part to be placed with your tweezers. Place it over the location where it goes, trying to keep it as squared and centered as possible to the pads. Use your iron to tack down the end over the tined pad. Now solder the other side (for chip resistors and caps), then flow some fresh solder on the tacked side. In the case of IC’s and transistors, make sure the part is still centered well over the remaining pads before soldering the rest of the pins. When soldering down the part, be sure to heat both the end or lead of the part and the pad it is to be attached too. Ideally, a little solder should flow under the end or lead of the part. Solder that sticks only to the top of an IC or transistor lead does no good.

BUILDING UP THE BOARD:

All the surface mounted parts are installed first. These go on the "top" side of the board (which will really be the bottom when we're done). Putting the parts in a small bowel after you open the package is a good way to keep from loosing any. A X2 parts placement diagram is supplied to help facilitate part locations. A number inside a part outline indicates it's value, while its part designation is located near by.

SOT-23 devices.

These are the black rectangles, with three leads, two on one side.

- ☐ Q1, MMBT3904 "1AM" NPN transistor
- ☐ Q2, MMBT3804 "1AM" NPN transistor
- ☐ Q3, MMBT3904 "1AM" NPN transistor
- ☐ Q4, ZXM61N02 "NO2" MOSFET
- ☐ D2, FMMV2105 "6J" Tuning diode
- ☐ D3, FMMV2105 "6J" Tuning diode
- ☐ U7, NJU7201U32 "DQF / 032" Regulator, this is the black rectangle with three leads on one side and the metal tab on the other.
- ☐ D1, FTDLL4148 This is the round glass part with two black lines. The thick line indicates the cathode and goes towards the line next to the part designation "D1" on the board.
- ☐ D4, shotky diode "K9 / V14" This a black rectangle with an tab on each end. The cathode end has a slight bevel to it, which is on the left hand side of the package when the lettering is "right side up".

Resistors.

Resistors are black on one side with the value marked in white epoxy. The last digit is the multiplier, so a 10 K Ω resistor is marked "103". We will work with one value resistor at a time, putting all of those down before going onto another value. Start with the smallest value resistors first and work up in value. So,

- ☐ R11 - 10Ω, "100"
- ☐ R2, ☐ R4, ☐ R21 -100Ω "101"
- ☐ R3, ☐ R8 - 330Ω "331"
- ☐ R15, ☐ R16, ☐ R17, ☐ R18, ☐ R22 - 4.7KΩ "472"
- ☐ R6, ☐ R7, ☐ R10, ☐ R19, ☐ R20 - 10KΩ "103"
- ☐ R1, ☐ R5 - 22KΩ "223"
- ☐ R13, ☐ R14 - 100KΩ "104"
- ☐ R9, ☐ R12 - 1 Meg Ω "105

Inductors

- ☐ L1, ☐ L2 10 μHy Dale 100 tan, with metal tabs on each end.

Capacitors

Capacitors have no markings, so you will have to be careful not to mix them up. Small value COG caps are pink in color and the higher values will be tan or brown in color.

□ C1, □ C4, □ C5, □ C7 - 22 pFd "pink"
□ C10, □ C12 - 47 pFd "pink"
□ C2, □ C3, □ C8, □ C9, □ C17 □ C20, □ C25, □ C26, □ C27, □ C28 - 0.001 μFd "tan or brown"
□ C29, □ C30 - 0.033 μFd "tan or brown"
□ C6, □ C13, □ C14, □ C15, □ C16, □ C18, C24, □ C33, □ C34, □ C36, □ C39, □ C40, □ C41 0.1 μFd "tan or brown"
□ C31, □ C32 0.22 μFd "tan or brown" .

IC's

Before you place the IC's, you need to know where pin 1 is. Pin 1 maybe indicated by a dot or dimple, a line along one edge of the package, or orientating the package so the writing is "right side up". Pin 1 will be in the lower left hand corner, when the line is to the left, the writing is "right side up" or the dot/dimple is also in the lower left corner. The pin 1 side of the IC goes towards the line with the notch in it on the board. Except for U6, all the IC's face the same direction.

□ U1 □ U2 - SA612A / □ U3 - MC145170D2 / □ U4 - 90S1200-12SC / □ U5 - LM386 / □ U6 -TS952ID

There are a few SMT parts on the "top" side of the board Install these now.

□ U9, TC7660
□ D5, D6 - FTDLL4148 - round bodied glass diode
□ C37, C38 - 10 μFd 16V electrolytic SMT

All the surface mounted parts should now be on the board. Inspect your work under the magnifier, making sure you soldered both ends of the resistors and caps. Use the tip of a sharp hobby knife to "nudge" the leads of the IC's. If any of them move, you didn't get solder to flow under the pin and stick it to the pad and must be redone.

THROUGH HOLE PARTS

- □ Socket for display. You will need to first prepare the leads on the socket before soldering to the board. The quickest way is to bend the leads out at right angles to the base of the socket, then trim them back to be about 1/16" long. You can also bend just the tip of the pin at a right angle, so the socket stands off the board. This will put the top of the display at the same height as most of the other parts to be put on this side of the board.
- □ X1, 10.240 MHz crystal
- □ C11, green trimmer capacitor. Note that the flat side of the trimmer goes towards the line on the component screen.
- □ C19 □ C21 3.3 μFd electrolytic capacitor
- □ C22 □ C23 □ C35 33 μFd electrolytic capacitor
- □ U8 LM78L05 regulator, TO-92 package.
- □ T1 □ T2 455 KHz IF transformer

- ☐ CF1 10.7 MHz ceramic filter. This is the reddish three legged part, dipped epoxy case. It goes in with the lettering facing in towards the center of the board.
- ☐ CF2 455 KHz ceramic filer. This is the red three legged part in the molded plastic case, marked “455A” Again, it goes in with the lettering facing towards the center of the board.
- ☐ L3, 16 turns, #24 wire on T37-6 toroid core.
- ☐ L4 ,10 turns, #24 wire on T37-6 toroid core.
- ☐ Mount L3 and L4 so that the core is snug to the board.
- ☐ J2, Stereo head phone jack
- ☐ J1, 0.7 mm coaxial power jack
- ☐ S1, S2 and S3, the three TAC push button switches
- ☐ The volume control

This competes the assembly of the board.

TEST AND ALIGNMENT

- ☐ Wire up the power plug.
- ☐ Solder a jumper or wire in a switch to the switch pads, located between the power jack and L4.
- ☐ Plug in the power jack and apply power.
- ☐ The display should come on and sequence the numbers 5. 2 0 0
- ☐ Connect a voltmeter between ground and TP1, the VCO control voltage test point.
- ☐ Using the band select function, select band [3], tuning the radio to 11.50 MHz.
- ☐ Adjust the spacing of the turns of wire on L4, so that there is 1.30 volts on TP1
- ☐ Using the band select function again, select band [0], 6.000 MHz.
- ☐ Adjust the spacing of the turns of wire on L3, so that there is 0.60 volts on TP1
- ☐ Connect a frequency counter to test point TP2, the VCO frequency test point
- ☐ Leave the radio set to 6.000 MHz or reload with band [0]
- ☐ Adjust the trimmer capacitor, C11, so that the VCO frequency is 16.705 MHz.
- ☐ If no frequency counter is available, tune to the radio frequency to a station you know the frequency of, then adjust the trimmer for clearest signal.
- ☐ The 455 KHz IF transformers should need no adjusting.
- ☐ The Nor’Easter should now be ready for use. Connect a 3-4 foot piece of wire to the antenna input, plug in a pair of stereo headphones and start looking for short wave stations.

TROUBLE SHOOTING

If you have any problems getting the receiver to work, the first thing to do is take a good look at your workmanship again. Most likely, you forgot to solder one end of a resistor or cap, or an IC pin. If the problem isn’t obvious, try to localize the problem area. Typical voltages are noted on the schematic for various parts of the circuit. Ideally, you will have an Oscilloscope handy to check the oscillators and such.

Possibly the most difficult area to trouble shoot is the overall PLL circuit. This is because it’s a closed loop and a problem in any area of the loop can make it not work. If the output of the loop amplifier, U6, pin 1, is at the positive supply rail, it means it is trying to reduce the VCO frequency. This could be because the input of the PLL chip, U3, pin 4, is not getting an input signal. This could be because either the VCO is not oscillating, or the buffer amplifier, Q1 is not working properly. Or it could be the PLL is not receiving data from the CPU. As you can see, it might take some detective work to find out what area of the loop isn’t working properly.

PACKAGING

The Nor'Easter board is sized so that it will fit into the ever popular "Altoids"® tin. However, the corners of the board will have to be rounded with a file before the board will fit. # 2 screws are used to secure the board to the tin or enclosure that's used. The shaft of the volume control is long enough to protrude through the lid of the tin, but the switches are not. The switches can be extended by using some plastic tubing over the shaft to make them the required length. Or, you can leave them as they are and operate the radio with the lid open. In this case, you may want to cut down the length of the volume control shaft, so there are no holes at all in the lid of the tin.

Since there isn't enough room in an Altoids® tin for even a 9V battery, you may want to make your own custom case, possibly out of copper clad board or maybe a thin wood. A switched ground pad is available next to the power jack for connecting the negative lead of the battery. By connecting the battery to the board this way, the battery will be disconnected when external power is used. If you add the optional on-off switch, a slide switch would be better than a toggle, as the side switch is less likely to be accidentally bumped "on".

Since the front end of the receiver is non-tuned, you might what to add a tuned circuit there. The tuning cap from a junk or cheap Wal-Mart AM/FM pocket radio would do the trick for the tuning cap. If adding a tuned front end, remove L1 and C1 from the board and jumper L1. You can also add a simple jfet preamp if you feel the need for additional sensitivity.

THEORY OF OPERATION

The Nor'Easter is a double conversion super heterodyne, using a 10.705 MHz first IF and a 455 KHz second IF. The receiver is digitally tuned, using a VCO and Phase Lock Loop circuit.

The antenna input circuit is comprised of L1 (10uHy) and C1 (22pFd) and is then coupled to the input of a SA612 mixer/oscillator, U1. L1 and C1 form a low pass filter, which helps keep local FM broadcast stations out of the mixer. Strong VHF signals can mix with harmonics of the VCO and cause problems. L1 also helps to base load the short wire used as an antenna.

The oscillator section of U1 is used as the first Local Oscillator. The tank circuit is comprised of the two coils, L3 and L4, and the varactor tuning diodes, D2, D3. MOSFET Q4 is used to short out L4, in order to increase the range of the oscillator. In order to work, a DC voltage needs to be applied to the Q4's drain and is supplied by R22, a 4.7K Ω resistor. The VCO signal is picked off the junction of the two oscillator feed back capacitors, C4 and C5. Q1 is used to isolate and amplify the VCO signal in order to drive the input of the PLL chip, U3. Q1 receives it's operating voltage from the U1, through resistor R1.

U3, a MC145170 PLL chip, contains the logic for controlling the VCO frequency. The chip is serially loaded with data from the μP controller, giving it the proper set-up information, divide ratio for the reference frequency and input frequency division ratio. The reference frequency is set to 5 KHz, which is derived from the 10.240 MHz crystal also used as the second LO. This sets the minimum tuning step of the receiver. The input divider (/N counter) is set to divided down the VCO to match the reference frequency. A Phase detector determines if the two frequencies match or not. Differential outputs of the phase detector drive the inputs of the loop filter, with a CMOS rail-to-rail output op amp as the active part of the filter. The phase detector drives the inputs to the op amp in such a way so that the output of the op amp produces the proper tuning voltage for the desired VCO frequency.

The output of the first mixer goes through a 10.7 MHz ceramic filter and then into the input of the second mixer, U2. Since a 10.240 MHz crystal is used to convert the 1st IF to the 2nd IF of 455 KHz, the actual 1st IF is 10.705 MHz. After being converted to 455 KHz by the 2nd mixer, the signal passes through a 455 KHz ceramic filter, which provides most of the receivers selectivity. The signal is then amplified by a high gain cascode amplifier, consisting of Q2 and Q3. "Back-to-back" 455 KHz IF transformer are used on the output of the amplifier, providing some additional selectivity. Since T2 is lightly loaded on it's output, it provides some additional passive gain. R5, a 1 megaohm resistor, is used to supply some forward bias to diode D1, which does the AM signal detection. The addition of the forward bias greatly increases the sensitivity of the receiver. The recovered audio then goes into the volume control and then into a LM386 audio amplifier

CAPS	VALUE	BODY COLOR	QTY	
C1,4,5,7	22p	PINK	(4)	
C2,3,8,9,17,20,25,26,27,28	1000p	TAN	(10)	
C6,13,14,15,16,18,24,33,34, 36, 39, 40, 41	0.1 μFd	BROWN	(13)	
C10,12	47 p	PINK	(2)	
C11	40 pFd Trim	GREEN	(1)	
C19,21	3.3 μFd /25V	Alum Electrolytic	(2)	
C22,23,35	47 μFd /16V	Alum Electrolytic	(3)	
C29,30	.033 μFd	TAN	(2)	
C31,32	.22 ufd	BROWN	(2)	
C37,38	10 μFd / 16V	4mmx5mm smt	(2)	
RESISTORS	**VALUE**	**MARKINGS**	**QTY**	
R1,5	22K	223	(2)	
R3,8	330Ω	331	(2)	
R2,4,21	100Ω	101	(3)	
R6,7,10,19,20	10K	103	(5)	
R9,12	1 MEG	105	(2)	
R11	10Ω	100	(1)	
R13,14	100 K	104	(2)	
R15,16,17,18,22	4.7 K	472	(5)	
SEMICONDUCTORS	**TYPE**	**PKG MARKINGS**		
Q1,2,3	MMBT3904	SOT-23 1AM	(3)	
Q4	ZXM61N02FCT	SOT-23 NO2	(1)	
D1,5,6	FDLL4148	LL-34 ROUND	(3)	
D2,3	FMMV2105CT	SOT-23 6J	(2)	
D4	FM5819	FM-1 Rectangle	(1)	
U1,2	SA612AD	SO-8	(2)	
U3	MC145170D2	SO-16	(1)	
U4	AT90S1200	S0-20L	(1)	
U5	LM389D	SO-8	(1)	
U6	TS952ID	S0-8	(1)	
U7	NJU7201U32	SOT-89	(1)	
U8	78L05	TO-92	(1)	
U9	TC7660	SO-8	(1)	
INDUCTORS				
L1,2	10 μHy	SMT1210 CASE	(2)	
L3	T37-6, yellow	16 turns #24		
L4	T37-6, yellow	10 turns #24		
T1,2	455 KHz IF	SUB-MINI	(2)	
MICALANIOUS				
X1	10.240 MHz	HC49/U		
CF1	10.7 MHz	CERAMIC FILTER		
CF2	455 KHz	CERAMIC FILTER		
S1-3	PB SWITCH	TAC		
14 pin dip socket				
display	MAN4910A	RED LED CA		
V1	50K	9mm VERT, audio	POT	
J1	0.7mm PWR			
J2	3.5mm	SMT Stereo		
PRINTED CIRCUIT BOARD				