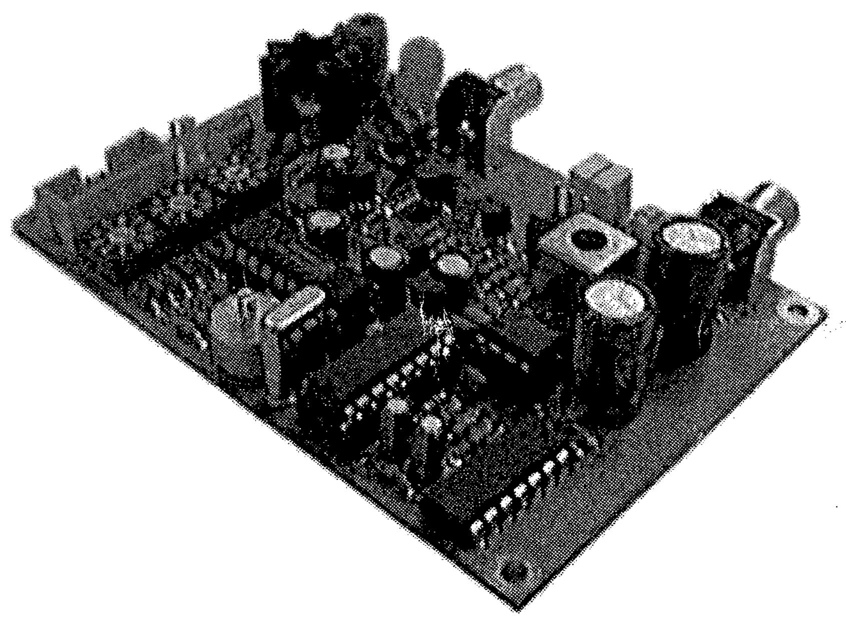
Broadcast Warehouse

PLL PLUS 1 WATT EXCITER

The Broadcast Warehouse BWPLL+ is a compact FM broadcast exciter with specifications that put many commercial exciters to shame. The modern innovative design allows audio and RF performance never before seen in kit or module exciters. The 'virtual VFO' dual loop system allows perfect audio flatness to below 10 Hz. AFC bounce and modulator overshoot are a thing of the past.You now can pass that low bass without distortion and get that perfect stereo separation that you have been demanding from your exciter. Broadband 'No tune operation' allows for ease of use. The only adjustment required is of the direct reading decimal dial switches for frequency selection. RF power is muted during out of lock conditions and the built in harmonic filter keeps your signal clean.The expansion connector allows for external modules to be connected to the board such as the Broadcast Warehouse BWPLL+ LCD.

Features

Phase locked loop system
Dual speed PLL
Low noise oscillator
Broadband design
No tune operation
Direct read switches
Very low distortion
Switchable pre emphasis
1 watt output
Harmonic filter
Expansion connector
Compact size
Black oxide high grade PCB



Specifications

Power output	1000mW +/- 100mW, 50 Ohms
Power requirements	13.3-16Vdc 300mA max
Harmonic output	60dBc
Spurious output	85dBc
Frequency steps	100kHz steps
Out of lock RF powerdown	-50dBc
Freq. stability	+/- 200Hz
Audio input level	adjustable
Freq. response	10Hz-100kHz
S.N.R.	>80dB
Distortion	<0.05%
Pre emphasis	None, 50us, 75us (switchable)

IMPORTANT INFORMATION : PLEASE NOTE!

Operation of this equipment without an appropriate license is an offense. Please check with your countries laws regarding operation of this equipment prior to switch on. It is the users responsibility to verify the local laws and regulations before-hand and Broadcast Warehouse and or its agents disclaim all responsibil-

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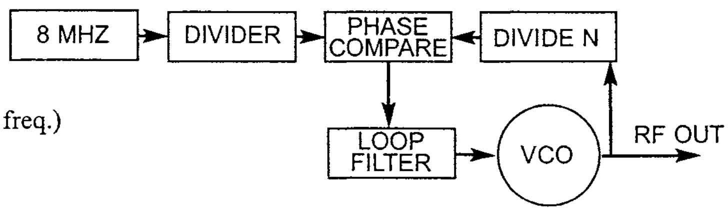
Principles of Phase Locked Loop systems

The Voltage controlled oscillator (VCO) feeds a portion of it's RF into one side of a phase locked loop chip. The other side of the PLL chip is fed with a reference frequency usually derived from a quartz crystal which is very stable. The Phase locked loop chip outputs a high or low voltage, High or low is subject to whether the reference frequency input is lagging in phase or leading in phase compared to the RF input from the VCO. In other words high if the reference frequency is higher in freq than the VCO frequency and low if the reference is lower. The Reference frequency is usually in the range of 10 khz to 100khz and also forms the step size of the VCO. A reference frequency of 100khz can not have a lower step size than 100Khz. Crystals are physically very large at these frequencys so we tend to use a higher frequency crystal and divide it down to our chosen reference frequency. The 100mhz signal from our VCO needs to also be divided down to the reference frequency and to do this we need a divide by N counter. N is any number which can divide our frequency to the reference.

The phase locked loop system will comprise of.

1. The VCO (voltage controlled oscillator)
2. The divide by N (100mhz to ref. freq.)
3. A stable crystal for the reference
4. A fixed divider (to divide the crystal to the ref. freq.)
5. A phase comparator
6. The loop filter (voltage smoother)



In the example below we will use a 8 mhz crystal, a reference of 100 khz and the RF frequency we will lock to is 99.9 mhz. The reference divider is 80 and the RF divider is 999.

The 8 mhz crystal is divided by 80 to 100Khz. This stable signal is fed into one of the inputs of the PLL chip. The RF signal from the VCO is fed into the divide by N counter. This counter will need to have N set to 999 to achieve a divide down from 99.9 mhz to 100 Khz. When the VCO has a frequency of 99.9 mhz both the inputs to the phase locked loop chip will have the same frequency and phase. The output pulses from the phase locked loop chip are fed into a loop filter circuit. This low pass filter circuit smoothes and averages the phase locked loop pulses and produces a dc voltage which is applied to the frequency determing element of the VCO which is usually a varicap diode. This moves the frequency of the VCO and the process is repeated. This is why the name LOOP is used. The frequency is checked against the reference, the voltage is changed in respect of any frequency error, the voltage is applied to the oscillator, the frequency moves. This process is happening continually with the PLL chip adjusting the VCO until it is on frequency and it will keep readjusting to keep it there. If we changed the divide by N number to 997 then the PLL would adjust the VCO until both inputs to the phase comparator were equal in phase and frequency. This would force the VCO to now have an output of 99.7 Mhz.

The broadcast warehouse phase locked loop system employs a modern chip that contains An oscillator for a quartz crystal, a divider for the reference, a divide by N counter and a phase locked loop section (phase comparator). All of these sections are configurable by serial control. This control is fed from a broadcast warehouse software program contained in a microcontroller. The loop filter is built around a standard op amp. Some exciters still use many logic chips for the various dividers and associated functions but the broadcast warehouse system uses only two if we do not count the loop filter section.

The problems of Phase Locked Loop systems

The loop filter is the most crucial part of the phase locked loop system and plays the biggest part in achieving a high quality exciter. The design goal is to have the PLL system get the VCO to the correct frequency fast and to appear transparent. When we FM modulate the VCO we are moving the frequency of the VCO in proportion to the audio signal we apply. The PLL circuit's job is to correct any frequency errors.

go hand in hand. If we design the loop filter too well the quick response will strip the audio and not allow any deviation and hence no or minimum audio. If we relax the requirement to allow better audio to pass uncorrected then we introduce other problems such as PLL lock time (the time it takes the PLL to correct any frequency or get the VCO to frequency). The ideal PLL system would allow us to get to frequency fast and then somehow relax itself and change the loop filter characteristics to improve the audio. We need the PLL circuit to not correct the audio (modulation) as much as when the VCO is genuinally off frequency.

Multispeed loop systems.

Multispeed loop systems can be designed in many ways. We have seen and tested systems from complex to the very complex. We have chosen a system that has a minimum component count and still retains excellent performance. We have managed to keep the component part down by putting the intelligence of the system into software. The Dual speed loop system we have used is only 1 extra component above our standard single loop system. This component is an analogue switch which has two of it's switches placed across two of the resistors in the loop filter. When out of lock the switch shorts out the resistors enabling more current to be dumped into the capacitors of the loop filter and hence quicker charge time and faster lock up. When on channel the switches are opened. The hard part is knowing when to switch. Some others exciters use the lock detect signals from the phase comparator chip to determine when the VCO is in lock. We have found this to be far from perfect as high level low frequency content in the audio (heavy bass) can make the lock signal from the phase comparator read wrong. This could cause the transmitter to switch to fast lock when heavy bass is applied and then we would be back to square one, distortion.
Broadcast warehouse has taken these lock detect signals from the phase comparator and connected then to a microcontroller where they are analyzed by a propriority software routine to determine whether the VCO is really ON frequency or off frequency. The software can detect that the VCO is still on frequency even if we deviate the carrier with audio by 1 mhz. This enables us to obtain very very low bass response with very very low distortion figures and still have an accurate lock detect system and fast lockup time.

Circuit Description

The frequency determing element is formed by coil L1 and varicap diode VD1 together with capacitors C17 - C20. These components are used as part of a cascode oscillator whose output is then buffered by transistor T3. The RF output from T3 is impedance matched to the base of transistor T5 by RFT1, a 4 to 1 matching transformer. The high power output from T5 is impedance matched
by coils L2 and L3 and associated capacitors to the 50 ohm output socket CON2. These components also provide harmonic filtering.

The PLL circuit is primarily IC2 which is a serially programmable PLL chip. The microcontroller IC3 reads the dial switches at switch on and outputs a serial code to the PLL chip in a format that determines the output frequency that the PLL will try and lock the transmitter to. The PLL chip outputs control pulses to the loop filter built around op amp IC4. The loop filter takes the sharp pulses from the PLL chip and converts them into a smoothed signal ready to apply to the frequency determing component, varicap diode VD1. IC1 is an analogue switch that shorts out two of the resistors in the loop filter which enables the transmitter to get on frequency faster. When the oscillator is on frequency the Analog switch switches out which greatly improves the audio response of the transmitter. The microcontroller IC3 determines when to switch the analog switch in and out by reading the lock detect signals from the PLL chip. The microcontroller can also use this information to switch off transistor T3 with open collector configured T4 which mutes the RF output when the transmitter is out of lock. LED1 provides visual indication of the PLL locked condition.

Audio is fed into the modulation input connector CON1. It is passed through a high frequency lowpass formed by C37, C38 and a ferrite bead to keep any RF from feeding back into the Modulation circuitry. From here the signal passes to variable resistor VR1 where modulation levels can be set. From the output of the variable resistor the audio signal passes through resistor R30 and jumper J1. This jumper allows either of capacitors C1 or C2 to be put in parallel with R30 forming a pre emphasis filter. 0, 50 or 75us is selectable

depending on jumper selection. From here audio is fed via a resistive potential divider to the varicap diode VD1. The audio imposed onto VD1 causes the frequency of the transmitter to shift and modulation is achieved.
There is an expansion connecter on the board to allow connection of other broadcast warehouse products such as an LCD frequency selector. Connection details are provided with the relevant expansion product.

Setup and testing

Make sure you have the PLL PLUS assembled before proceeding, consult the assembly instructions for more info. Once constructed the BWPLL+ should not need any alignment.

POWER SUPPLY
Ok! now that the unit is assembled and you have double checked for construction errors we can get ready to switch on the unit. For correct full band operation you will need a regulated power supply that is capable of giving out between 13.8 and 15 volts. 13.4 volts is the minimum needed to allow the PLL to cover the full 87.5 to 108 mhz . 15 volts is a safe maximum voltage. Any more and the components may run too hot. If you do not supply a minimum of 13.4 volts then we cannot guarantee that the PLL will work correctly at the top of the band. 12 volts may only allow the unit to lock to 105 mhz or so. With the correct supply to hand connect a 50 ohm load to the PLL. A dummy load is preferred over an antenna.

FREQUENCY SELECTION
Before you turn the power on you must select your frequency.
The first switch represents units of 10 mhz, where 8 would mean 80 mhz. 0 = 10 = 100 mhz
The second switch represents units of 1 mhz where 9 would mean 9 mhz.
The third switch represents units of .1 mhz (100khz) where 7 would mean 700 khz

Taking the above as an example if we set switch 1 to 8, switch 2 to 7 and switch 3 to 9 we would set the PLL to a frequency of 87.9 (8X10MHZ+9X1MHZ+7X.1MHZ)
If you select an invalid frequency then the lock led will flash repeatably and no RF output will occur on any frequency.
To reset a new frequency you must turn power to the unit off then back on again.

If you have a frequency meter you can also fine tune the frequency by the adjustment of VC1. for example 99.200001 instead of 99.201341. Disconnect the audio before trying to adjust VC1. You will obviously need the unit on and powered up first before this adjustment can be made. If you don't have a frequency meter don't worry. The unit will still be in spec.

AUDIO INPUT AND PRE EMPHASIS
Audio is fed in via RCA/PHONO connector CON1. If you have a stereo encoder then remove the jumper J1. If you have an audio limiter with pre emphasis capability then also remove the jumper J1. Otherwise if no stereo encoder or limiter with pre emphasis is in line
with PLL you should configure jumper J1 to suit the pre emphasis requirement for your region. 75us for the USA and Japan and 50 for the rest of the world. With your audio applied at the desired level to the BWPLL+ adjust variable resistor VR1 for 100 percent modulation (a maximum peak deviation of +/- 75khz)

RF OUTPUT
The RF output can be connected to CON2 or you can solder to the pads on the top or the bottom of the board. The RF output power from the BWPLL+ is fixed at about 1W and can not be adjusted. Please do not alter the coils L2 and L3. They form part of the harmonic filtering and should not be adjusted. If you require less power then use a resistive attenuator formed from three resistors. Details in any good radio handbook such as the ARRL handbook. Always connect a good 50 ohm load on the output to Avoid damage to T5.

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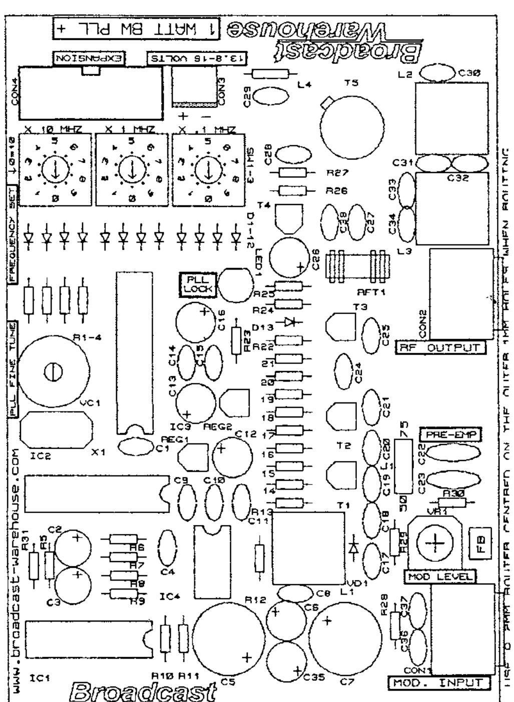
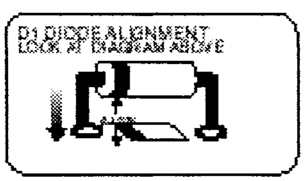
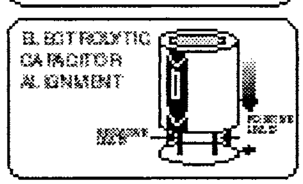
Assembly Instructions

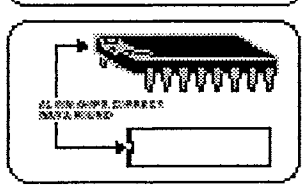
This kit is not really a first time kit builders project. If you have not soldered before we recommend you get some soldering experience from a simpler project or get this kit assembled by someone who has previous experience in electronic construction and soldering.

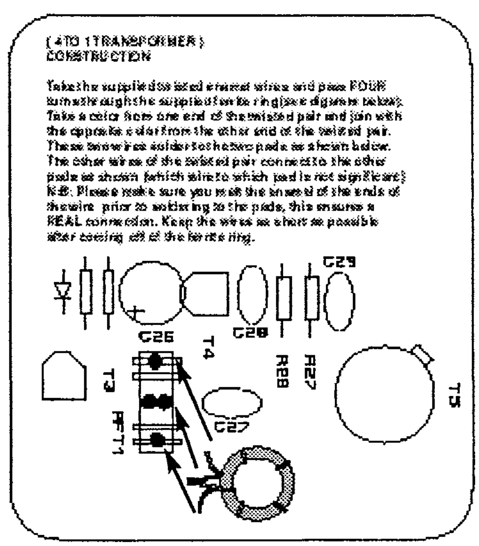
1. Empty the contents of the kit and proceed to check all of the components off against the component list, It is a good idea to tick off each component as you go through. When you have double checked all the parts proceed.
2. We always start with the lowest height components first which are the resistors. Insert each resistor and solder one at a time taking care to make a good joint and not to short across any other pads/holes. Double check the component is the correct one before soldering.
3. Now insert and solder Diode's D1-D13 observing the polarity (SEE DIAGRAM). Do the same for varicap diode VD1 and inductor L4. Ferrite bead (marked FB) is next.
4. Next its time to insert the ceramic capacitors C1, C4, C8 ,C9, C10, C11, C14, C15, C18, C19, C20, C24, C25, C27, C28, C29, C30, C31, C32, C33, C34, C35, C37 and C38 These are non polarized and can be inserted and soldered either way around.
5. Switches 1 to 3 should be next and these can be followed by the chip holders for IC1-4, Make sure you line the notch on the chip holder with the notch on the ident on the printed circuit board. This will help in making sure you insert the chip the correct way around in the socket.(SEE DIAGRAM)
6. Variable resistor VR1 should be put in next followed by voltage regulators REG1 and REG2 and then transistors T1-T4. Led LED1 should be next making sure the flat on the led aligns with the flat on the silkscreen ident on the PCB. Transistor T5 can be inserted and soldered next, Leave the heatsink for T5 off for now.
7. Now insert the polarized electrolytic capacitors C2, C3 , C6 , C10, C13, C16 and C26 MAKING 100% SURE they are soldered in correctly. (SEE DIAGRAM) The board has a positive symbol next to the positive hole of each polarized capacitor. Insert the negative stripe side away from the positive (+) marking. Now insert ceramic capacitor c17.
8. Insert and solder jumper J1. you may if you wish put the jumper tab's on, but we recommend you wait till the end when we will configure the settings of the board. The pre emphasis capacitors C22 and C23 can be put in next. Connecters 1 to 4 can be soldered in if you wish to use them. Variable capacitor VC1 is next.
9. Inductors L1 (metal can) and plastic type L2 and L3 can be inserted next followed by crystal X1. The push on heatsink for T5 can now be pushed on, Taking care to avoid twisting and damage to the transistor.
10. The large electrolytic capacitors C5 and C7 are next once again observing the polarity like before with the smaller electrolytics.
11. Make the rf transformer from the toroid core and twisted enameled wire as shown in the diagram.
12. Oh! you can now insert all of the chips into there correct chip holders.!!!
It is advisable that you check your work and all the components are where they should be and that there are no solder splashes or shorts underneath the circuit board. It is better to spend five minutes double checking everything rather than risk damage at switch on due to a mistake during assembly.
If you are sure everything is ok you can proceed to the setup and testing page.











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Component list

COMPONENT	VALUE	MARKING / IDENTIFICATION
R1,2,3,4,6,7	10K	BROWN,BLACK,ORANGE,GOLD
R5,8,9,31	330K	ORANGE,ORANGE,YELLOW,GOLD
R10,R11	330R	ORANGE,ORANGE,BROWN,GOLD
R12,16,17,22,23	1K2	BROWN,RED,RED,GOLD
R13,20,24	4K7	YELLOW,PURPLE,RED,GOLD
R14,30	12K	BROWN,RED,ORANGE,GOLD
R15,26	220R	RED,RED,BROWN,GOLD
R18	180R	BROWN,GREY,BROWN,GOLD
R19	68R	BLUE,GREY,BLACK,GOLD
R21,28,29	470R	YELLOW,PURPLE,BROWN,GOLD
R25	10R	BROWN,BLACK,BLACK,GOLD
R27	2R2	RED,RED,GOLD,GOLD
VR1	1K POT	SMALL YELLOW POT MARKED 102
C1	39PF	39PF
C2,3,6,35	2.2UF	2.2uF
C4,8,11,14	100N	104 OR 100N
C5,7	470UF	470uF
C9,24,27	82PF	82PF
C10,15,29	10N	103 OR 10N
C12,13,16,26	100UF	100uF
C17	220PF	220PF
C18	4.7PF	4P7 OR 4.7PF
C19,30	27PF	27PF
C20,33	56PF	56PF
C21	NOT USED	
C23	4N7	4700
C22	6N8	6800
C25,28,32,38	1N	102 OR 1N
C31	12PF	12PF
C34,36,37	33PF	33PF
IC1	4066	4066
IC2	MC145170	MC145170
IC3	PIC16CXX	PIC16CXX
IC4	LF351	351
T1-T4	MPSH10	MPSH10
T5	2N4427	4427
L1	5-1/2 MC120	METAL CAN 00754
L2	2-1/2 S18	RED COIL
L3	3-1/2 S18	ORANGE COIL
L4	.15 UH INDUCTOR	YELLOW AXIAL uH15
LED1	RED LED	RED LED
REG1	78L05	78L05
REG2	79L10	78L10
X1	8 MHZ CRYSTAL	8.000
VC1	5-65 PF TRIMMER	YELLOW ADJUSTABLE TRIMMER
SWITCH1-3	DECIMAL ROTARY SWITCH	BLACK SWITCH MARKED 0-9 IN CIRCLE
D1-13	1N4148 DIODE	4148
VD1	BB909A VARICAP	BLACK AXIAL WITH YELLOW STRIPE
CON1,2	RCA/PHONO CON.	RCA/PHONO CONNECTOR
CON3	2 PIN MOLEX SOCKET	2 PIN MOLEX SOCKET CONNECTOR
CON4	10 WAY IDC CON.	10 WAY RIBBON SOCKET
J1	3 PIN JUMPER HEADER	3 PIN HEADER
HEATSINK	CLIP ON HEATSINK	BLACK FINNED HEATSINK
RFT1	TOROID AND WIRE	BLUE/YELLOW RING WITH ENAMELED WIRE
8 PIN IC SOCKET X 1	8 PIN IC SOCKET	8 PIN IC SOCKET
14 PIN IC SOCKET X 1	14 PIN IC SOCKET	14 PIN IC SOCKET
16 PIN IC SOCKET X 1	16 PIN IC SOCKET	16 PIN IC SOCKET
18 PIN IC SOCKET X 1	18 PIN IC SOCKET	18 PIN IC SOCKET
PCB	BLACK BOARD	YOU ARE JOKING!

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