NETOMETER-1

refining the art of frequency maintenance

COMPLETE DOCUMENTATION
Revision 1.0

www.netometer.co.uk

Netometer-1 Introduction

The Art of Frequency Maintenance.

For many years now the frequency accuracy and stability of transmitters have been taken as a given. Crystal based frequency synthesisers and DDS signal sources, often temperature controlled, have made such issues a thing of the past.

However, the re-emerging interest in vintage radio, particularly AM radio, takes us back to the days of free running VFOs where net channels were measured to the nearest kilocycle (on a good day).

It seems only proper that vintage equipment, often lovingly and meticulously restored, should not only be cosmetically perfect but also electrically perfect. But electrically perfect means true to the original design for better or worse, often complete with *designed-in* intermodulation distortion, poor spectral purity, and of course frequency drift.

Time though has moved on, and operating such wayward equipment on today's exacting amateur bands warrants a certain sense of responsibility on the part of the operator.

Focusing here on the frequency stability issue, it is unreasonable to expect such classic equipment, liberally sprinkled with miniature furnaces, to hold station as case temperatures rise and every coil, capacitor, nut and bolt expand and contract under the unremitting strain of the laws of thermodynamics.

"Blaming a transmitter that drifts is no excuse for transmitting a signal that drifts."

The solution is obvious – monitor the transmitter's frequency, then set and correct as needed.

Step forward the frequency counter
Frequency counters are nothing new of course, and most shacks will have one, even if the on/off switch remains a mystery. Useful devices, but are they always the best solution?

As with most digital readouts, the digital counter display cannot be taken in at a glance. *Eyes are analogue*. More challenging still is to work out if the frequency is too high or too low. To make matters worse the readout won't lock properly with an amplitude modulated carrier.

Shall I Compare Thee?
Where the requirement is for an indication of merely being *on-channel*, and where the channel frequency is already known, what is needed is not a frequency *counter*, but rather a frequency *comparator*. Comparing where you *are* with where you *should be* doesn't need a digital readout, just some sort of indication of being higher or lower. Ideally, a simple display that can be understood at-a-glance. Such a device appears thus far to be unavailable.

Introducing "The Netometer"
So it was then that the Netometer came to be. A frequency comparator with a centre-zero style readout comprising nothing more than five LEDs,. No thinking, no calculating, just an intuitive tweak of the VFO knob to keep things central.

Netometer has five pre-settable channels. Select the channel required then transmit. Watch the centre zero LED display and adjust your VFO accordingly. That's it, netting done in seconds.

The set starts to drift. Netometer displays the offset, tracking the discrepancy. The operator then completes the control loop by manually altering the transmit frequency to cancel the drift and re-balance the LEDs to centre-zero again. Fuss-free and instinctive.

Netometer ~ refining the art of frequency maintenance

Contents

Section 1 Circuit Description

1.1 Overview

Netometer is essentially a microprocessor controlled frequency comparator. Most of the functions required are implemented in software, making the hardware element low-cost and simple to build.

1.2 Block Diagram

Figure 1.1 below shows a block diagram of the various component parts illustrating how much is software based.

- RF from the LM319N input amplifier is fed to the frequency counter which is enabled for a period determined by the gate timer (100ms).
- After checking the frequency is in-range, the count value is fed to the frequency comparator where it is compared to a pre-stored value retrieved from eeprom memory. The result is fed to the display driver which drives the appropriate LEDs.
- Any carrier dropouts caused by amplitude modulation peaks are picked up by the Envelope Dropout Detector and stored in the Dropout Counter. Any count above zero causes the Frequency Counter to be reset.
- The economiser saves power in Standby Mode by taking 1ms samples every 100ms until a valid signal is detected.
- The Low Voltage Detector triggers a display change to indicate low battery volts when the supply falls below 4V.
- To save battery life the Timeout Timer automatically powers the unit off after 30 minutes on standby.
- The system clock is derived from a 20 ppm 20MHz crystal.

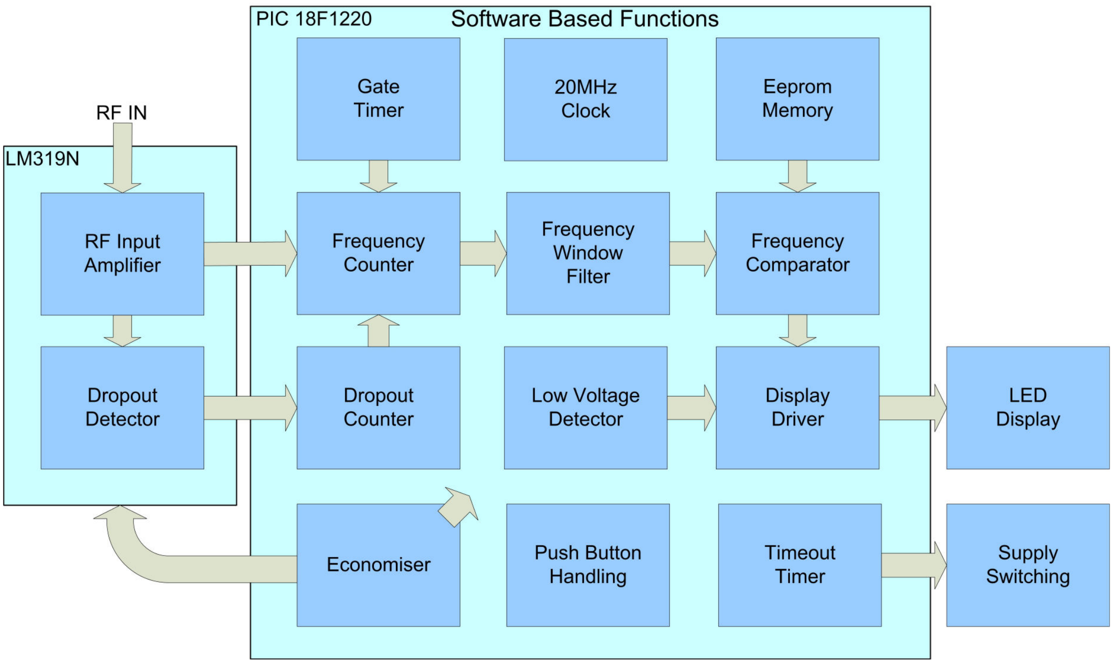


Figure 1.1: Block diagram

The following paragraphs refer to Figure 1.3: Circuit Diagram at the end of this section.

1.3 RF Amplifier.

Input signals are amplified by the LM319N high speed comparator U1/a, then fed to the PIC chip via R8. This chip was chosen for its low cost, predictable performance and ease of use. It is also readily available in a DIL package. U1/a has an open collector output, and the load is provided by R4.

Input sensitivity is defined by the bias voltage across the input pins 4 and 5. The voltage is derived from the potential divider formed by R1,R2 and R3, with approximately 2.8mV appearing across R2. This is sufficient to keep U1/a output high unless triggered by an input signal.

The input pins sit at around half rail voltage (2.5V) for best sensitivity and frequency response. The input signal path is C1, R2, and C2. The RF input is dc isolated by C1. C2 decouples the input signal to 0V, without which there would be no differential signal voltage across R2. Thus the input impedance is close to 50 Ohms (predominantly R2) and the input sensitivity 10mV RMS (-27dBm) or better. This compares favourably with typical bench frequency counters.

In Standby Mode U1 is activated for 1ms every 100ms by means of the economiser rail which connects the negative pins of U1 to 0V through a low impedance PIC I/O line (U2 pin1). This short time period minimises power drain while still leaving enough time for an incoming signal to be detected, after which Netometer goes into Count Mode and U2 pin1 stays low. R3 is not connected to the economiser line as this would result in a much longer settle time as C2 charges and the bias volts change.

…….. >

1.4 Envelope Dropout Detector

The output of U1/a (pin12) is also connected to the Envelope Dropout Detector. When amplitude modulation is applied to the carrier, most frequency counters tend to under-count, especially at lower input levels. This is because when the troughs of the modulation envelope fall below the counter input threshold the counter will miss counts. The result is a constantly changing display. With Netometer, a solution was found using a combination of hardware and software that detects bad counts and stops them reaching the display.

The input bias for U1/b is derived from the same resistor network that biases U1/a ~ R1, R2, and R3. The static differential voltage across the input pins 9 and 10 is derived from the drop across R6 caused by the input impedance of the comparator’s negative input, pin 10. Thus the positive input is higher, resulting in a 5V static output at pin 7, reducing current drain. The high value of R6 reduces the loading on the low pass filter R5/C3 for best sensitivity. C4 is a DC isolation capacitor. C5 cleans up U1/b output by removing any residual RF.

When envelope dropout occurs gaps appear in the amplified signal at U1/a pin 12. This is shown in figure 1.2b below (the example shows a single 1kHz modulating tone for clarity).

These gaps (audio pulses) are extracted from the RF waveform by the low pass filter R5,C3 and fed to U1/b for amplification (figure 1.2c), resulting in 5V negative going pulses appearing at U1 pin7 (figure 1.2d). The traces in figure 1.2 show an extreme example, but in normal use the sensitivity of the circuit is such that impending envelope dropouts are detected and signalled to the PIC before the RF waveform breaks up sufficiently to disturb the count.

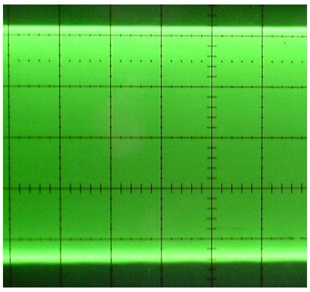


Fig 1.2a. Clean RF

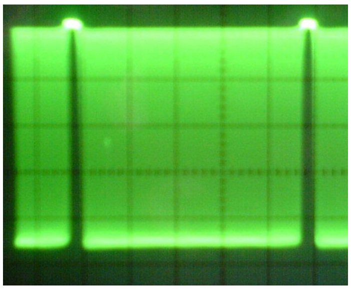


Fig 1.2b. Envelope Dropout

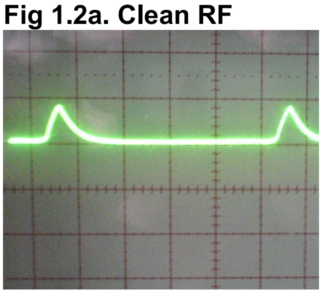


Fig 1.2c. LPF o/p from C3

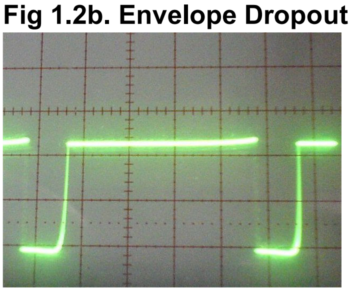


Fig 1.2d. U1 pin 7

Figure 1.2. Typical waveforms showing operation of envelope dropout detector.

1.5 LED Display

LEDs D1~D5 are low current high efficiency LEDs, chosen to reduce current drain and to allow direct drive from the PIC. LED current is limited by resistors R11 ~ R15.

1.6 Supply Switching

Part of the design brief was to produce a device with a single push button to control all functions. Thus a way had to be found to also power the unit on and off from the single button.

This is accomplished by Q1, Q2, D6 and PIC software.

The push button (normally open) is connected from the un-switched positive supply to U2 I/O pin 6 (set as an input). Pin 6 is also connected to 0V via R7. Thus the PIC sees either a logic “0” or a logic “1” when the button is pressed.

1.6.1 Start-up

Assume the unit to be powered down. Q1 is cut off as there is no power to the PIC and thus no voltage possible on pin 7. Q2 is cut off as long as Q1 is cut off.

When the push button is pressed, D6 is forward biased, bypassing Q2 and applying power to the 5Volt rail. The PIC then starts up. The first thing the PIC does is check whether pin 6 is high. If it is, it assumes start-up has been via the push button as opposed to the PTT option (see below), and immediately outputs 5V on pin 7 thus turning on Q1. Q2 is now turned on via Q1 collector/emitter and R16. The push button can now be released as the PIC now assumes responsibility for power management by maintaining 5V on pin7

1.6.2 Power-down

Pressing the pushbutton for two seconds whilst in Standby Mode triggers a power-down sequence which flashes the LEDs appropriately then removes the 5V from pin 7, the *suicide* pin, cutting off Q1 and Q2 and removing all power.

1.7 PTT Option

D7 and R17 can be added if separate control over power-up and power-down is required from the transmitter PTT line (of course in any event the complete power management circuitry can be omitted and a simple on/off toggle switch added instead).

D7 isolates the circuitry from any residual PTT line standing voltage. R17 limits Q2 base current.

Assume the unit is powered down. When the PTT line is taken to 0V, Q2 is cut on via D7 and R17, applying power to the 5V rail. The PIC then checks to see if pin 6 is high. If it is not, as will be the case here, it assumes PTT power-up is being used, and pin 7 is not raised to 5V. Q1 will not therefore keep Q2 alive. Thus when the PTT line is released, Q2 cuts off immediately removing power from the 5V rail.

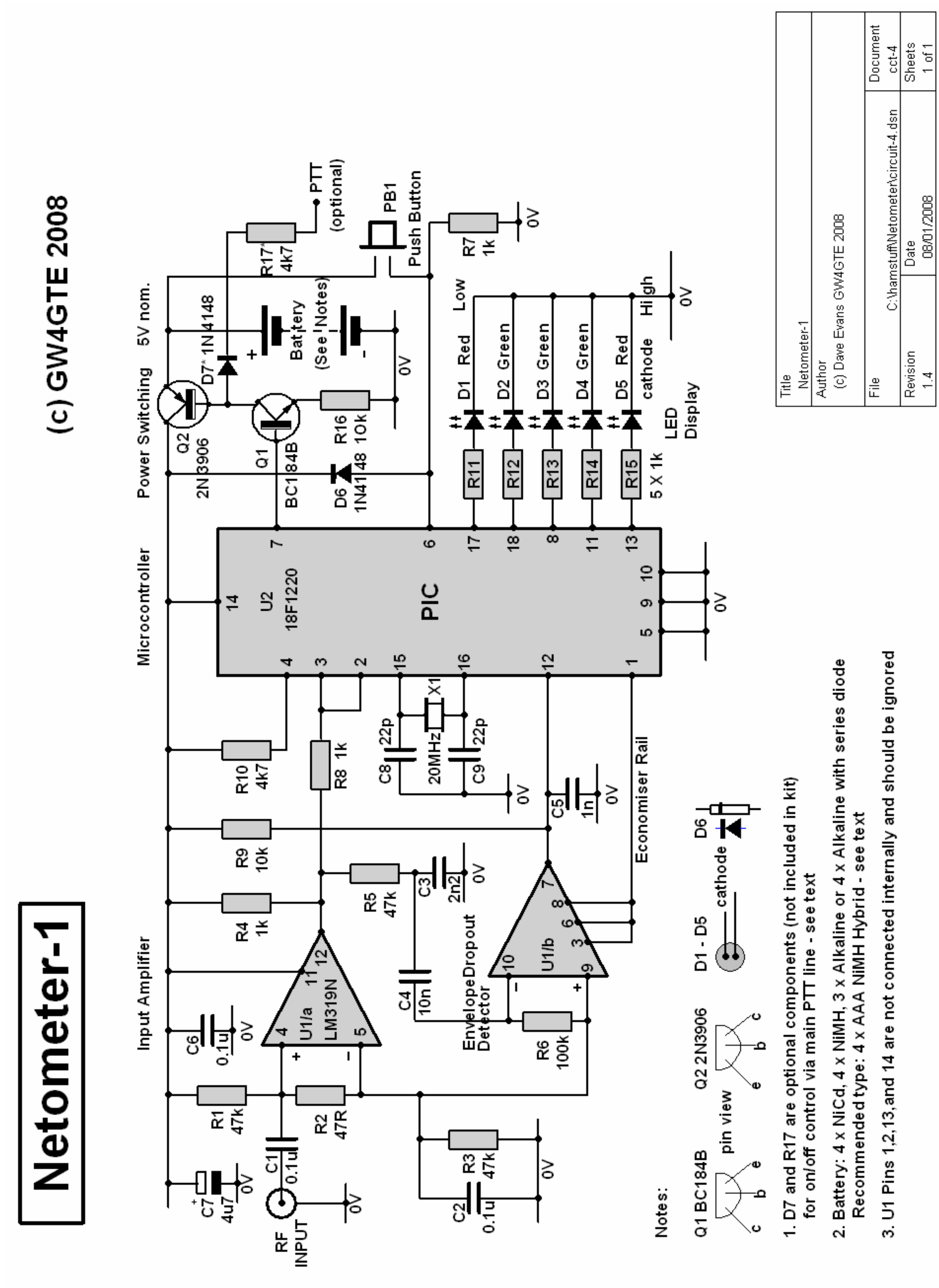


Figure 1.3: Netometer Circuit Diagram

Section 2 Software Description

Most of the functionality of Netometer is contained within the PIC chip U2. This functionality is achieved by a combination of program code, hardware features of the PIC, and the code required to set-up and use the required hardware features.

This section is not intended to be a course about PIC programming ~ on which Microchip and many others offer a wealth of application notes and tutorials. Instead each software function shown in figure 1 above will be described from the point of view of what it does and why, rather than how.

2.1 Frequency Counter

This uses Counter0, one of four counters available within the PIC. There is also a selectable pre-scaler associated with Counter0 and this is used to prevent timer overflow at higher frequencies. At the end of the gate period the value in the counter is one tenth of the actual frequency being counted. This is because the gate time is 100ms.

2.2 Gate Timer

The Gate Timer is actually a software function. Counter0 is enabled, then a 100ms software delay is implemented before the counter is disabled. The gate time was chosen as a compromise between counter resolution and display refresh time. The 100ms gate time gives 10Hz resolution, which is adequate accuracy, and which also allows a refresh time of around 105ms making the LED display very responsive when netting onto channel or correcting frequency drift.

2.3 Envelope Dropout Counter

Pulses from the Envelope Dropout Detector are fed into Counter1 within the PIC. At the end of the 100ms gate period Counter1 is checked, and if there are any counts the value in Counter0 is cleared and the count restarted. Counts in Counter1 imply that the input signal has been disturbed by modulation and the accuracy of the main count compromised.

If the Netometer display configuration was set to show modulation detection, the LED display is momentarily blanked when modulation is detected and the current count cycle aborted. See the Operation Manual for details on how to set the display configuration.

2.4 Frequency Window Filter

For reasons explained above (See Envelope Dropout Detector) the input count is validated against the operating window of 1MHz to 9MHz. If the input frequency is outside those limits the LED display will flash appropriately to indicate this. See 6.11.4 for MORE details.

2.5 Frequency Comparator

Once a 100ms sample count has passed the “dropout” test and the Frequency Window test, it is offered to the frequency comparator. This is the heart of the Netometer. The comparator compares the incoming count with the count stored in eeprom memory for the channel in use. The result is passed to the Display Driver.

2.6 Eeprom Memory

The count values associated with each channel, along with other system information e.g. current channel number and current display mode are stored in eeprom (electrically erasable programmable read only memory). Data can be updated over one million times, and data retention is longer than forty years. The count stored is approximately one tenth of the frequency in Hz as it is the value Counter0 reached after the 100ms gate time when that channel was programmed.

2.7 Display Driver

The value resulting from the Frequency Comparator function is passed to the Display Driver code which then decides on the LED display pattern required, driving the appropriate LEDs.
See the Operations Manual for details on the display pattern for various frequency errors.

2.8 Timeout Timer

If Netometer was powered up using the push-to-start method, a 30 minute timeout timer is started. This is reset back to 30 minutes every time the unit drops into Standby Mode from Count Mode. If the timer reaches zero the unit is powered off automatically by removing volts from U2 pin 7. This conserves battery life if Netometer is inadvertently left on. In fact the Standby Mode power consumption is so low due to the economiser that power-off can always be left to the system to manage.

2.9 Economiser

The design brief called for a battery powered unit with low power consumption. In use Netometer will spend more time in Standby Mode than in Count Mode. Also there is more scope for reducing power in Standby Mode as most parts of the device do not have to operate all the time. So the design includes an economiser function that operates in Standby Mode.

Under software control the PIC is placed in *sleep mode*, awakening every 100ms for 1ms. In *sleep mode* the PIC draws microamps rather than milliamps. During the 1ms period U2 pin 1 is connected to 0V within the PIC itself. This briefly powers up U1 long enough for any input signal to appear in Counter0. If there is no input signal, U2 pin 1 reverts to 5V disabling U1 thus reducing its current drain to zero, and the PIC goes back to sleep again for another 100ms.

2.10 Low Voltage Detector

The facility exists within the PIC for a software programmable low-voltage indicator to be implemented. When in Standby Mode and the operating voltage falls to 4V, the channel LED single flash will change to a double flash. Testing the supply voltage in Count Mode is not necessary, and in any case would compromise the accuracy of the 100ms gate time

Netometer will operate satisfactorily down to a supply rail of approximately 3.5V with a slight reduction in sensitivity.

2.11 Push Button Handling

The PIC also contains code to detect when the push button has been pressed. The action taken depends on what mode Netometer is in at the time, and in some cases, the duration of the press. Because press duration is a factor, push button commands are not always actioned at the first as soon as the button is pressed. See Section 6 for more information.

Section 3 Design Notes

This section discusses some of the Netometer design aspects in more detail.

3.1 Range of Frequencies covered

The Netometer frequency window of operation exceeds the design brief which specifies a device to cover 160m, 80m and 40m, by covering 1MHz to 9MHz.

Ultimately the limiting factor for upper frequency performance is the slew rate of U1, and performance degrades rapidly above about 11MHz. This chip was chosen for its low cost, predictable performance and ease of use. It is also readily available in a DIL package.

The lower frequency limit is ultimately defined by the economiser sample time of 1ms. However the performance of the Envelope Dropout Detector starts to degrade before these limits kick in. This is due to the simple single-pole low-pass filter R5, C3 and to the sensitivity required from the following amplifier U1/b in order to detect the first hint of envelope break-up before it compromises the count.

As the input frequency falls, the low-pass filter becomes less effective at discriminating RF from AF until there is enough residual RF level fed to U1/b to permanently generate output pulses, thus aborting every count and effectively paralysing the unit.

Above about 9.5MHz the second harmonic of the input signal beats with residual RF from the 20MHz PIC clock oscillator to again produce a resultant frequency which the low pass filter does not fully filter. A higher order low-pass filter would cure this but was thought unnecessary bearing in mind the target operating bandwidth is already exceeded. Alternatively the software could be modified to disregard dropout pulses at lower and higher frequencies but this would lead to an inconsistent LED display if dropout indication was selected.

3.2 Input Impedance

The input impedance of U1 is nominally 50Ohms (R2). A low impedance was deliberately chosen to dramatically reduce the chance of the unit false-triggering on stray RF fields. Netometer is quite sensitive, comparing favourably with a typical laboratory frequency counter also set to 50Ohms e.g. Racal-Dana 1998. Such counters however exhibit false triggering using a wire pick-up when set to high impedance input.

3.3 The Economiser

The economiser uses the “sleep” facility of the PIC, during which its current consumption is virtually zero. The PIC’s watchdog timer is used as a wake up call. 1ms is enough time to see if there is RF present before going back to sleep. The LM319N draws several mA of current so it was decided to gate that off as well during PIC sleep time thus reducing power consumption further. Economiser pulses look like envelope dropout pulses to the PIC but they are “time-windowed” out in software.

The economiser also performs a secondary function. With a basic frequency counter, the first count will almost always read low as the input frequency will have appeared some time after the gate time started thus less counts accrue than should do for a full count. There are many ways around this both hardware and software. In this case the economiser effectively acts as a gate synchroniser as the real gate period of 100ms is only started after it is established that there is a frequency to be counted. This prevents the first LED display indicating low. (The same issue applies on the final count where the input is removed during a gate period. This is solved in software)

3.4 The Frequency Counter

The frequency counter function uses PIC Timer0 which has an optional pre-scaler. The pre-scaler is enabled to prevent the main counter overflowing at higher frequencies. However the pre-scaler value is not directly readable so its value has to be deduced at the end of each gate period using a software technique described by Microchip in Application Note AN592. This is why the amplifier U1/a feeds PIC pins 2 and 3 in parallel. See www.microchip.com for more information.

3.5 The Gate Timer

The 100ms period does not have to be exactly 100ms but it does have to be consistent. This is because the Netometer is effectively self calibrating. Let’s take an extreme example and suppose the 100ms is actually 101ms. The longer gate time will mean Counter0 contains a 1% higher count than it should do. If that value is stored as a reference, as long as the 101ms stays as 101ms, any incoming counts that are subsequently compared will also read 1% higher, and so you are still comparing apples with apples. Any error between reference frequency and input frequency would be wrong by 1% of the *offset* rather than 1% of the *actual* frequency. So a 100Hz error would be 101Hz in this example ~ irrelevant in a 10Hz resolution system.

Ultimately gate accuracy and stability depends on clock accuracy and stability. The 20MHz system clock uses a 20ppm crystal as opposed to the more common 30ppm version, and the associated capacitors are low-k types for better stability. Low capacitor values have been used for minimum loading and the oscillator may be several kHz high as a result. As discussed above, the system is self calibrating and stability is the important issue.

3.6 Netometer-2

Should there be a requirement for a future version covering a wider frequency range then an improvement to the frequency response of the input amplifier would be required. A more expensive higher slew-rate device could be used with little circuit redesign, or a different circuit altogether. The PIC clock could be increased up to its design limit of 40MHz (albeit with increased current drain), but ultimately the counter clocking limit for the PIC will be reached, requiring complete redesign, or possibly an external hardware pre-scaler to front-end the RF input to the PIC. A divide by two pre-scaler along with a doubling of the gate time to 200ms would be a good compromise for maintaining resolution whilst still leaving the unit reasonably responsive.

Most of the component parts of a frequency stabilised VCO are present. Instead of driving LEDs from the frequency difference signal, generate a voltage to control a varicap to keep an oscillator on channel. e.g. PWM or D/A circuitry. Not a practical system for a VFO, but possibly useful when using fixed channels for AM use. Plans are underway to develop a channelized solid-state Codar AT5. The PA, driver and modulator design have been prototyped, and a PIC in either Netometer mode or D/A mode (probably using Microchip D/A over I2C bus) could handle frequency generation using a 7.2MHz ~ 8.0MHz VCO, /2 for 80m, /4 for 160m.

Section 4 Construction and Testing

This section of the Netometer manual covers construction and testing. For a description of how it works please refer to the "Circuit Overview" and "Circuit Description" sections. For how to use it please refer to the "Operations Manual".

You will need to refer to the circuit diagram shown in figure 1.3 above and the layout diagram figure 4.1 below to complete this section. The circuit and layout diagrams are also included as separate .png (Portable Network Graphics) files, and for better clarity these should be opened and printed full size from a suitable image editor.

The parts list for Netometer is shown at the end of this section (Table 4.2), and is also included as a separate file ("Netometer_parts.doc"). You may wish to print out a copy of the parts list to check the components against if you have received a kit of parts. The only additional parts you will need are an RF input connector if required (as opposed to a piece of wire as an RF pick-up), a small piece of circuit board (see below), and a suitable case.

4.1 Choosing a Power Source

Netometer requires a 5Volt supply at up to 25mA. You can power the unit from batteries (AAA holder supplied, batteries not supplied) or via a separate power source of nominally 5Volts.

The device was designed for low power consumption to make battery power feasible, but bear in mind the properties of different battery types. NiMH batteries (4 x AA or AAA) are suitable for frequent Netometer use where their high rate of self-discharge will not be the primary limiting factor. If the device will see only occasional use then consider the newer Hybrid types which have a slightly lower capacity than normal NiMH cells but have a substantially lower self discharge rate. Alternatively, long shelf life alkaline cells are another possibility.

! ***Note: If using Alkaline cells, use either three cells, or place a silicon diode in series with four cells to lower the voltage, otherwise the PIC chip's maximum supply voltage will be exceeded.***

4.2 PIC Chip Firmware

If you have received a kit, the 18F1220 PIC chip will have been programmed with the latest firmware and functionally tested before shipping.

If you decide to source your own components you will still need your PIC to be programmed. A *free* programming service for UK builders. Just send your PIC chip together with an s.a.e. to the address given in www.netometer.co.uk and your programmed and tested chip will normally be sent back to you by return. Alternatively programmed chips can be supplied at cost plus a small handling charge. A complete kit of parts as listed in table 4.2, including a programmed PIC is also available.

4.3 Board Layout

Netometer is not a complicated circuit to build. All the components are a reasonable size and there are no surface mount parts. Assembly of the main board should take no more than 2-3 hours if all the parts are readily to hand.

Figure 4.1 below shows a suggested layout that uses standard 0.1” spacing Vero/Strip board. This layout is recommended as it has been tested several times with no problems found to date, although alternatives would work just as well as there are no layout-critical components.

The components are mounted on a 22 x 16 matrix with conducting strips running across the width i.e 22 strips of 16 holes. You will probably want to leave extra space either side for mounting holes.

Experienced constructors may find the circuit and layout diagrams provide sufficient information, and choose to bypass the detailed construction description. Please however note the sections about testing in case of problems. Re-join the text at “Netometer Power-up” towards the end of this section.

☑ As you work through the stages of construction and testing you may wish to tick off each task as it is completed using the tick box at the end of each sub-section.

4.4 Board Preparation

Select a suitable piece of circuit board. Resist the temptation to get on with the soldering, and firstly decide how you intend to mount the board in the case of your choice (you do have a case in mind?). Cut the board to size, and drill any mounting holes in the circuit board as required. Allocate three rows of track for mounting holes, and drill through the middle row of the three using component holes as templates. Carefully drill a shallow countersunk hole from the non-copper side then drill through from the copper side. This minimises board and copper track damage. Practice on an off-cut first.

Taking into account the reserved area for mounting holes, the matrix size needed is 16 x 28 (i.e. 16 x (22 + 2 x 3)). Or the less convenient albeit symmetrical 22 x 22 ((16 + 2 x 3) x 22). If the circuit board is “old stock” or the copper track looks tarnished in any way lightly go over the track with a fine sanding block until the copper is bright. This will make soldering easier later.

☐ Now mask off the non-component copper strips (the ends for the mounting holes) with tape to avoid confusion when placing components, so that you only see the component matrix. Use a light coloured tape and draw arrows with felt pen to indicate board orientation to help avoid getting the board upside down during construction.

4.5 Cutting the track

Having prepared the board, the first thing to do is make the cuts in the track. There are 22 cuts in total. As the saying goes measure twice, cut once. Figure 4.1 is shown from the component side, so you are looking through the board with x-ray vision to where the track cuts are. (If you turn the board over like the page in a book, left and right will be reversed as you look at the track from the track side). Mark out the locations for the cuts with a dab of felt tip pen then re-check before you remove any copper. Note the cuts under U1 and U2 are all in line even though U1 and U2 are offset one row. Don’t forget the five cuts under R11-R15. The row you choose to cut is not critical but keep them in line for consistency.

Be careful cutting the copper. An expensive track removal tool can be purchased but just as effective after a little practice is a 1/8" drill bit in a pin vice. Using a small amount of pressure twist the drill by hand. Try this on an off-cut first as once the copper is penetrated it's very easy to drill straight through the board. (It's not a disaster if you do, but it doesn't look pretty). Check the drill cuts have properly isolated the track – too small a drill size or too shallow a cut can leave slivers of track still in place. Clean up any burrs and visually check. If in doubt, test across the break with a continuity tester.

4.6 Solder in the IC sockets

Now it's time for some soldering. Mount the two IC sockets first, taking care with orientation and track positioning. Pin 1 is to the bottom left (the pin 1 end of the sockets has a small indent in the plastic between pin 1 and pin 14/18). Firstly just attach the sockets to the board with two dabs of solder at diagonal ends of each socket e.g. pin 1 and 8 for U1, 1 and 10 for U2. Re-check they are in the correct place on the board. Check they are level, and flush with the board. Re-dab the joints and correct if not. Then solder all remaining pins before going back and making a good job of the first two pins.

Recheck the position of the sockets again. Are the track cuts in the correct place under the sockets? You will undoubtedly use the sockets as landmarks for placing other parts so accuracy here is important. Now visually inspect the solder joints to make sure there are no bridges between the tracks.

4.7 Solder in the wire links

Next install the wire links. There are 15 in all. Referring to Fig.4.1, place the links on the component side, and solder in place. There is no need for the wire to be insulated. Strip the insulation off some single core equipment wire. For the smaller lengths you could use off cuts from component leads. Stop the wire from moving before soldering by bending it in the direction of the copper track (i.e. at right angles to the run of the wire). Don't put the bends in line with the wire as there is a risk of shorting to the next track or component. Take particular care with the links under U1 – remember the sense is reversed as you turn the board over.

4.8 Solder in the resistors

The first components to be attached should be the resistors. This will allow us to make some useful resistance checks before going any further. Bend the wires under the board as advised for the wire links. Tick off the components in table 4.1 as they are soldered in place. You may wish to follow the component order in table 4.1 or referring to Fig. 4.1 use a board edge or the IC sockets as a reference and work from there. R2 and R6 are mounted vertically, all the other resistors are mounted flush with the board. Try to keep the coloured resistance bands the same way round to ease identification later if needed. When you are finished, count the resistors. There should be sixteen in total. Now check they are all in the right place.

4.9 Continuity Checks

This is a good time to do some continuity checks. Use Table 4.1 below to make resistance checks using an auto-ranging multi-meter set to ohms. Lead polarity is not important.

Test #	From	To	Value Expected	Component
1	U1 /11	U2 /14	s/c	Links
2	U1 /3	U1 /6	s/c	Links
3	U1 /3	U1 /8	s/c	Links
4	U1 /3	U2 /1	s/c	Links
5	U1 /7	U2 /12	s/c	Links
6	U2 /2	U2 /3	s/c	Links
7	U1 /5	U1 /10	s/c	Links
8	U1 /11	U1 /4	47k	R1
9	U1 /11	U1 /12	1k	R4
10	U1 /4	U1 /5	47R	R2
11	U1 / 5	U2 /5	47k	R3
12	U1 /9	U1 /10	100k	R6
13	U1 /12	U2 /3	1k	R8
14	U1 /11	U2 /4	4k7	R10
15	U1 /11	U1 /7	10k	R9
16	U2 /5	U2 /6	1k	R7
17	U1 /12	LH end of R5	47k	R5
18	U2 /5	RH end of R16	10k	R16
19	U2 /18	Top end of R12	1k	R12
20	U2 /17	Top end of R11	1k	R11
21	U2 /13	Top end of R15	1k	R15
22	U2 /11	Top end of R14	1k	R14
23	U2 /8	Top end of R13	1k	R13

Table 4.1: Resistance checks

☐

4.10 Solder in the all capacitors

Observe the polarity of C7. Take care with C8 and C9 which are soldered under U2. Capacitor markings are coded: 1n = 102, 10n = 103, 0.1u = 104, 2n2 = 222. C8/C9 have no markings.

☐ Visually check there are no solder bridges under U2 around C8/C9

4.11 Solder in the transistors. Do not solder in D6

☐ Now attach Q1 and Q2 following the pin positioning in the layout diagram figure 4.1, taking care not to mix the transistors up. Q1 is NPN and Q2 is PNP so they are not interchangeable. Install the transistors the right way up, pins towards the board.

4.12 Supply Voltage testing

Connect PB1, and the battery box c/w batteries or other power source (5V) as shown in figure 4.1.

Using a loop of wire (resistor off-cut) temporarily short together U2 /6 and U2 /7.

Using a multi-meter set to Volts, carry out the following tests to verify the supply switching function of Q1/Q2

Test #	From	To	Value Expected	Component
24	U2/14 (+ve lead)	U2/5	0Volts	Supply Off
Now push and hold PB1				
25	U2/14 (+ve lead)	U2/5	~ 5V	Q1/2 switching
Release PB1, remove shorting link U2 /6~ U2 /7 and remove the supply voltage				

☐

4.13 Solder in D6

☐ Solder in D6, observing the diode polarity. The dark band goes to U2 pin 14. Visually check the nearby track under U2 for solder bridges. Visually check the diode, reconnect the supply and carry out test #26:

Push and hold PB1				
Test #	**From**	**To**	**Value Expected**	**Component**
26	U2/14 (+ve lead)	U2/5	~5V	D6
Release PB1 and remove the supply voltage				

4.14 Attach X1

☐ The final component to be soldered to the main board is the 20MHz crystal X1. The layout diagram shows a smaller crystal case for clarity. Carefully bend the pins to fit the correct holes. Space the crystal away from the board slightly to clear the resistors and links underneath. The crystal is self supporting.

4.15 Attach the LEDs

☐ Finally, attach the LEDs to the locations marked. The longer (+ve anode) pins go to the dropper resistors on the board, the shorter ones to 0V. The constructor may wish to mount the LEDs through drilled holes in the chosen enclosure, or on a small piece of strip board.

Construction is now complete apart from inserting the ICs.

4.16 Testing U1

Insert U1 taking care to ensure it is the correct way round. When pin 1 is to the left, the writing should be the right way up. **Do not insert U2**

Using a loop of wire temporarily short together U1 /6 and U2 /5.
Short out PB1 and apply volts so that the main supply rail is powered via D6.

Carry out the following checks:

27	U1 /11	U1 / 6	5V nominal	5V rail
28	U1 /4	0V	2.5V nominal	U1/a bias
29	U1 /10	0V	2.5V nominal	U1/b bias
30	U1 /12	0V	5V nominal	U1/a static o/p
31	U1 /7	0V	5V nominal	U1/b static o/p

☐ Remove the supply volts, un-short PB1 and remove the link U1 /6 to U2 /5

4.17 Insert U2 and Power Up

Insert U2, taking care to orient the chip as U1.

You are now ready for the big moment…

- Re-connect the power source,
- Press and hold PB1 until all 5 LEDs light then immediately release PB1. *LED3 should now be flashing about once per 1.5 seconds.*

- Press and hold PB1 again until all 5 LEDs light then immediately release. *The LEDs will display a power-off sequence then go out.*

Congratulations. Your Netometer is working!

Now turn to Section 5: Getting Started
You will need to perform some initial set-up steps before you can start using Netometer effectively.

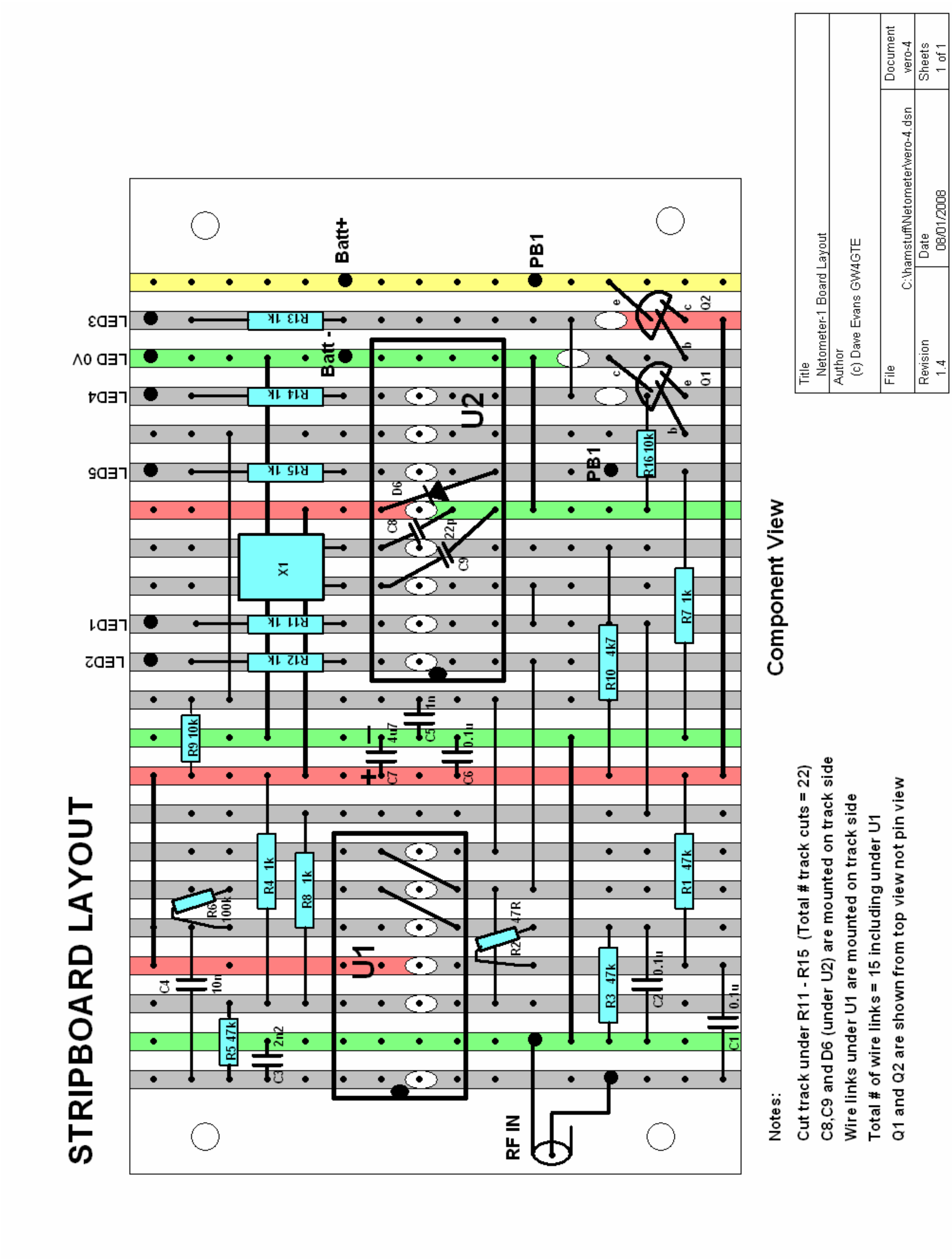


Figure 4.1: Layout Diagram

Parts List

This page is also included as a separate file "netometer_parts.doc"

Netometer-1 parts list		
Ref	**Value**	**Comments**
R1	47k	All resistors 5% ¼ W carbon film or better
R2	47R	
R3	47k	
R4	1k	
R5	47k	
R6	100k	
R7	1k	
R8	1k	
R9	10k	
R10	4k7	
R11	1k	
R12	1k	
R13	1k	
R14	1k	
R15	1k	
R16	10k	
		All caps 10% ceramic unless stated
C1	0.1uF	Marked as 104
C2	0.1uF	Marked as 104
C3	2n2	Marked as 222
C4	10n	Marked as 103
C5	1n	Marked as 102
C6	0.1uF	Marked as 104
C7	4u7	electrolytic >10Vwkg
C8	22pF	Low-K ceramic (no markings)
C9	22pF	Low-K ceramic (no markings)
D1	LED red	3mm low current type
D2	LED green	3mm low current type
D3	LED green	3mm low current type
D4	LED green	3mm low current type
D5	LED red	3mm low current type
D6	1N4148	Or similar
U1	LM319N	High speed dual comparator
U2	PIC 18F1220	Microcontroller (pre-programmed) #
Q1	BC184B	Or similar general purpose small NPN
Q2	2N3906	Or similar general purpose small PNP
X1	20MHz	HC49/U (20 ppm preferred)
PB1		Single pole push button non latching
BH1		Battery holder 4 x AAA (or 4 x AA)
SK1		14 pin DIL IC socket
SK2		18 pin DIL IC socket

See www.netometer.co.uk for details on how to order a programmed chip

Table 4.2. Parts List

Section 5 Getting Started

Read this section through before starting in order to place each instruction in context.

To properly use Netometer, two steps need to be carried out.
- Firstly a sufficient RF input level must be established.
- Secondly the unit must be accurately calibrated for accurate results.

5.1 Step 1. Setting the Correct RF Level

Netometer can work down to an RF input level of a few millivolts, but for best performance under modulation a carrier level of around 50mV to 250mV is recommended. The user will need to decide how to achieve this. There are two basic ways – direct connect and indirect connect. If a frequency counter has been used previously try the same method first. Test the method on all bands that will be used (160m/80m/40m).

5.1.1 Indirect Connect

Depending on the field strength available, a length of wire say 1m long may suffice. Establish the minimum length of wire needed to get a lock then at least double it for best modulation performance (This method may not work if the antenna is some distance away). Some ATUs have an RF pick up tap (or one could be added), and this could be tried also.

5.1.2 Direct Connect (preferred)

The best method is to take a sample off the transmitter's main output via an attenuator. For example, if the coax run to the Netometer is short, make up an adapter cable, junction box, or otherwise tap in at a suitable point in the feeder run and connect a 33k 0.5W resistor to the coax inner. Connect the other end of the 33k via screened cable to the Netometer RF input. You may need to try a smaller value resistor for carrier levels under 5W. Alternatively use a small toroid over the inner with a few turns as secondary, much as an SWR meter pickup. If a dummy load can be used during testing instead of the antenna so much the better.

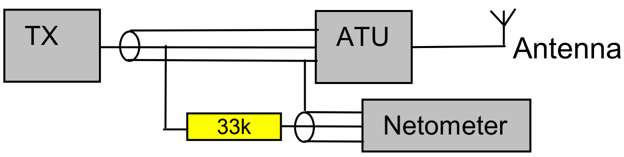


Figure 5.1 Direct connect suggestion

The RF coupling methods are just suggestions. It doesn't matter how coupling is achieved as long as there is enough RF level for correct operation. You may initially wish to experiment with the Netometer functions using a directly connected signal generator (an MFJ259 works well also but it's very unstable).

- Having chosen an RF coupling method, switch Netometer on (See 6.1 below). After switch-on the unit will be in Standby Mode and a single LED will flash approximately once every 1.5 seconds denoting the channel in use.

- Now transmit on your favourite net channel, checking the band for occupancy first (or more preferably using a dummy load). If the RF input level is sufficient Netometer will go into Count Mode and the LEDs will now display frequency error rather than channel number. The chances are that one or other red LED will be flashing at a fast rate.

5.2 Step 2. Calibration

Assuming step 1 is successful and a sufficient RF level achieved, we can now carry out a test calibration to establish the method and understand what's happening before looking at ways of performing a final calibration.

5.2.1 Test Calibration

- Still transmitting, press and hold the push button until the three green centre LEDs light, then release the button. The LEDs should stay lit (or centre green only – see 6.3 below).

The incoming frequency has been stored and Netometer is now using that as a reference.

Give in to temptation and play a little. Move your transmit frequency up and down slightly and watch the LEDs change. ***This is what Netometer is all about***. Hopefully at this point any further explanation is unnecessary, and the ease of use should be immediately apparent.

Study Table 6.2 in Section 6 below to better understand what the LEDs are saying.

That's all there is to calibration i.e. storing a frequency as a reference. Of course only one channel has been set up. There are five channels. Try setting some of the others as well:

- Stop transmitting
- Change channel (see section 6.7 below)
- Transmit (maybe try another frequency)
- Press and hold the push button until the green LEDs light then release the button
- Repeat per channel

Any channel can be set to any frequency from 1MHz to 9MHz. The settings are stored in non-volatile memory. Channels can be changed as often as required although the intended use is for the channels to be accurately set to an operator's favourite net frequencies then left.

As the unit is crystal controlled, in a normal room environment calibration drift is not an issue. However Netometer can only be as accurate as the original reference frequency.

5.2.2 Final Calibration

Having established the method of calibration and tried a few test settings, the channels i.e. the reference frequencies should be programmed as accurately as possible. There are many ways to achieve this. Here are a few possibilities:

- Connect a frequency counter in parallel and adjust the transmitter
- Directly connect an accurate digital signal generator
- Directly connect an analogue signal generator and frequency counter
- Use a modern digital transceiver as an RF source

5.3 Checking the Envelope Dropout Detector (optional).

Once a suitable RF level has been established, check the envelope dropout detector by changing the configuration settings (See 6.3 below) setting the Dropout Display to "on". Modulate the transmitter with speech at a normal level and note the flickering of the LEDs. This is normal, and confirms the envelope dropout circuits are working correctly. The LEDs should flicker less when using a lower voice level (if speech processing is used this may not happen). As a side-effect, the dropout display can act as a very basic modulation monitor; however this mode is mainly intended for testing, and for normal operation Dropout Display should be set to "off".

Section 6 Operating Manual

Netometer is intended as an aid to setting and maintaining the frequency of transmitters that require external resources for this to be carried out accurately.

It is more convenient and intuitive than the standard digital frequency counter as no mental calculations are required to establish frequency setting and correction.

All functions are carried out using a single push button. The push button (PB) performs different actions depending on the operating mode and the length of time the button is held.

There are three transient states and two operating modes

Transient states:	**Operating Modes:**
Power-up	Standby Mode
Power-down	Count Mode
Configuration	

6.1 Power-up

Press and hold PB until all five LEDs light then immediately release.

The LEDs will extinguish, followed shortly after by a flash of a single LED at approximately 1.5 second intervals. Netometer is now in Standby Mode.

6.2 Power-down

To power down the unit manually from Standby Mode (i.e. no signal input, with channel LED flashing) press and hold PB until all five LEDs light then release PB. The LEDs will go through a power down sequence after which the power is removed.

6.3 Configuration Settings

There are four configurable display options that can be set according to user preference. To enter configuration mode start with the unit powered off. Then press and hold PB as for a normal power up, but keep PB pressed until the five LEDs extinguish, then release PB. Netometer is now in configuration mode and the current setting, retrieved from Eeprom, will be displayed according to table 6.1 below. Each time PB is pressed the display moves to the next option in round-robin fashion.

The options allow the user to select the *on-frequency* display mode, and the envelope dropout display mode.

Configuration display		Operational display	
# LEDs lit	**Flashing LEDs**	**On-freq. display**	**Dropout Display**
3	no	3 greens	off
1	no	1 green	off
3	yes	3 greens	on
1	yes	1 green	on

Table 6.1. Configuration settings

There is a resettable two second countdown timer which is reset each time the next option is selected. After two seconds Netometer will go into Standby Mode having stored the new configuration setting in eeprom.

6.4 On-Frequency display

Netometer indicates an on-frequency signal by lighting the inner LEDs – either the middle LED (LED3) or all three green LEDs (LEDs 2-4). The recommendation is for all three green LEDs to light up. The alternative of a single LED may be preferred, also making possible a different LED layout where two LEDs in series can replace

LED3. These could be mounted above each other to give a different display pattern to five LEDs in a row. (Use a lower value resistor for R13).

6.5 Envelope Dropout Display

At higher modulation levels, and especially at lower carrier levels, troughs of the signal envelope can momentarily fall below the input amplifier threshold resulting in an incorrect display. Setting *Dropout Display* to *on* will indicate when dropout pulses are detected. The recommended configuration is for this to be set to *off*. When set to *on*, the display will flash momentarily during dropouts.

This can be used as a crude form of modulation indicator, and as an aid to setting the correct RF input level. If the LEDs flash at the slightest hint of modulation then the RF input level should be increased. At 100% amplitude modulation the LEDs will always flash on speech peaks regardless of signal level.

Dropout display, when set to *on*, will flash the display on speech peaks regardless of the LED pattern being displayed. i.e. not just when on-net.

6.6 Standby Mode

After power up, with no signal present, the unit enters Standby Mode. Standby Mode is indicated by a single LED flashing at approximately 1.5 second intervals. The LED in Standby Mode represents the channel number that is being used for the reference frequency, i.e. LEDs 1 – 5 represent channels 1-5. It is up to the user to remember the target frequency set for each channel.

The push button allows the operator to carry out two operations whilst in Standby Mode: power the unit off (see above) and change channel.

6.7 Changing Channel

To change channel, press PB to advance the channel by one, in a round-robin fashion. The current channel LED will flash during this process. When the desired channel is reached do not press PB again. After two seconds the display will revert to the normal two second flash. The new *current channel* number is stored in eeprom and recalled on next power up.

6.8 Count Mode

Netometer enters Count Mode when a valid carrier is detected. In Count Mode, the LEDs cease to be channel indicators and they now become frequency error indicators. *This is the primary function of Netometer*. The incoming frequency is compared with the stored frequency for that channel.

The carrier must be of sufficient amplitude to drive the circuitry, and be within the correct frequency window. *See the Specification for more details.*

In Count Mode, PB performs only one operation: setting the reference frequency for the channel in use. See *Calibration* below for more information. In Count Mode PB cannot alter the channel number, or power the unit off. These are Standby Mode functions.

6.9 Calibration

This can only be done in Count Mode. Having selected the desired channel when in Standby Mode, apply a steady RF signal at the desired reference frequency. Ignore the LED display which will almost certainly show an error. Press and hold PB until the display changes to the on-frequency display of three centre green LEDs (or one centre LED if selected) then release. The frequency is now stored in eeprom against that channel. When the channel is selected from now on, incoming frequencies will be compared to it and any error displayed as shown in Table 6.2 below. Calibration need only be carried out once per operating frequency. Netometer of course is only as accurate as the calibrating signal.

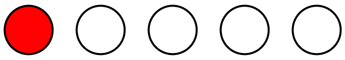
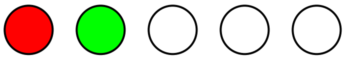
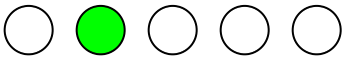
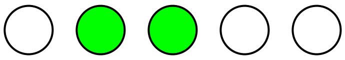
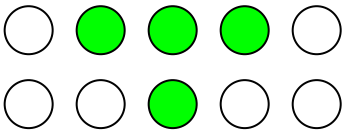
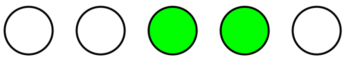
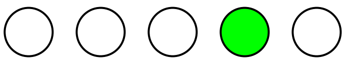
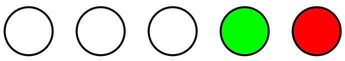
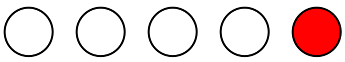
LED Display	Signal Frequency Error
	>500Hz below reference frequency. Flashing LED indicates error > 2500Hz.
	>250Hz below reference frequency
	>100Hz below reference frequency
	>50Hz below reference frequency
	On Frequency +/- 50Hz Three LEDs (default) or single LED as set in configuration options.
	>50Hz above reference frequency
	>100Hz above reference frequency
	> 250Hz above reference frequency
	> 500Hz above reference frequency. Flashing LED indicates error > 2500Hz.

Table 6.2. LED Display

6.10 Error display interpretation.

The cut-over points between different LED displays have been carefully chosen to give a tighter tolerance towards net (50Hz steps in the "green zone" with double that at the centre). A centre frequency accuracy of better than 50Hz can be achieved if required by rocking the VFO either side, interpolating the result. Note the resolution is 10Hz.

Netting Rules-of-Thumb.

- Only green LEDs lit = Frequency is within 250Hz.
- Green and red LEDs lit = At least 250Hz off net. Adjustment advised.
- Only red LED lit = At least 500Hz off net. Adjustment required.
- Red LED flashing = At least 2500Hz off net. Adjustment urgently required.

Keep It Green!

6.11 Other Netometer Features

Netometer has several other features built in for your operating convenience. These features are permanently enabled.

6.11.1 Auto power-off

After approximately 30 minutes in continuous Standby Mode, Netometer will automatically power-down to preserve battery life. The 30 minute timer is reset each time the unit enters Standby Mode. There is no timeout in Count Mode.

6.11.2 Low Battery Indication

If the operating voltage falls to a value of nominally 4Volts, then in Standby Mode the single LED flash changes to a double LED flash. The unit will continue to operate down to nominally 3.5Volts allowing time for battery replacement.

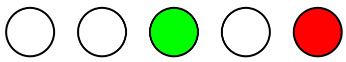
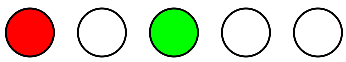
6.11.3 PTT option

With reference to the circuit diagram, if D7 and R17 are installed, the unit can be powered up from the PTT line. Earthing the PTT line will power up the unit. Removing the earth will immediately power Netometer down.

With PTT line on/off control, Netometer will go straight into Count Mode if it sees RF at power-up. The channel cannot be changed in Count Mode, so set the desired channel first by using the push button to power on, set the channel, then power off again.

6.11.4 Input frequency out of limits

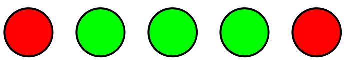
In Count Mode if the operating frequency window is exceeded, the display will flash thus:

Flashing 	Input frequency above 9MHz operating limit (reliable up to approx. 10MHz)
Flashing 	Input frequency below 1MHz operating limit (reliable down to approx. 100kHz)

Note: When the LEDs show *out of limits*, the incoming frequency cannot be saved to a memory, and the push button is inoperative until the frequency is removed or brought into range.

Section 7 Specification

Frequency coverage (limits set in software):	1MHz to 9MHz
Frequency stability:	Better than +/- 30ppm/degC
Frequency accuracy:	within 10Hz of stored channel assuming constant temperature
Modulation Types:	CW, A3E, FM, PM and other symmetrical sideband carrier modes
Gate time:	100ms
Resolution:	10Hz
Sample rate:	> 9.5 samples/sec
Input impedance:	Nominally 50 ohms
Input sensitivity:	Less than -25dBm (12.5mV pd.)
Maximum input:	Greater than +13dBm (1V pd.)
Amplitude modulation immunity:	>50% mod. (1kHz tone) at -10dBm (70mV pd.)
Envelope Dropout suppression:	Automatic
Envelope Dropout indication:	Settable as visual (LEDs flash) or no indication
Frequency error indication means:	Five LEDs. Two reds, three greens
On-channel indication:	Settable as centre green LED or all three green LEDs
Channel indication:	The five LEDs double as channel indicators in Standby Mode
LED error calibration:	Indications from <2.5kHz to > 2.5 kHz (See Operation Manual)
Channels:	5 reference frequencies can be stored in eeprom
Device timeout:	Unit will auto power off after 30 minutes (+/- 10%) on Standby
Controls:	Single non-latching push button
Voltage requirements:	Nominally 5V Max. 5.5V. Min. 3.5V
Low voltage detection threshold:	Nominally 4V
Low voltage indication:	Double flash of channel LED in Standby Mode
Current Drain in Standby Mode:	< 500uA, with 100ms 3mA pulse every 1.5s
Current Drain in Operating mode:	20~25mA at 5V depending on LED status



Keep It Green