Chapter 16

Miscellany

A 10GHz Prescaler

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Background and design aspects

This unit is a practical way of extending the range of a frequency counter. It uses the Fujitsu FMM110VJ chip to divide the input down by a factor of eight. Working over the frequency range of approximately 1 to 12 GHz, it was built to fit directly onto the input socket of an inexpensive frequency counter, successfully extending its range up to 12GHz.

Most low cost frequency measuring equipment currently available won't measure much above 3GHz or so. The Watson F-128 is typical of the low cost units and is good up to 2.8GHz and cost about £60. It works well and is reasonably accurate (it can be calibrated and zeroed in to a frequency standard).

For 10GHz the author used to rely on a cavity wavemeter which, with much eyestrain, is able to measure frequency to within 2MHz or so over the range 8GHz to 12GHz. This is fine for ensuring transmission is within the band and for setting up TV transmitters and other wide band gear but it is not good enough for setting up narrow band beacons, etc, to more precisely known frequencies. With this prescaler ahead of a frequency counter, measurements can be made up to about 12GHz provided that the input is between 0.1mW and 10mW (the chip has an absolute maximum rating of 20mW input power so there is a bit in hand). The accuracy of the overall system is totally dependent on the basic accuracy of the counter used – even a fairly ordinary crystal oscillator is accurate to 10 parts per million. This would give an accuracy at 10GHz to within 100KHz and with careful calibration at a stable temperature the accuracy can be improved to the order of 1KHz. or better - a far cry from the 2MHz accuracy of a cavity wavemeter.

It should be noted here that many frequency counters give a much better display resolution than their accuracy would imply. In other words they display many digits but they all might not all be accurate. This feature can only be checked by calibration against a known frequency standard such as WWV or MSF.

This particular prescaler design was conceived after reading the Dubus Technik IV publication (Ref. 1), which gave details of a design using the Fujitsu FMM110HG package, but at a cost of $300. The author contacted Fujitsu (Ref. 2) who kindly provided information and current prices for this and another smaller cheaper package with similar performance – the FMM110VJ. This latter unit was available in small quantities for about £20 inc. VAT. This was very encouraging and a couple of them were ordered and work started on laying out the PCB.

The circuit (fig.1) follows that shown in the data sheet for test purposes and a decision made at the outset was that no exotic components would be used if they could be avoided. All the other components were in fact SMDs salvaged from old LNBs or other microwave boards. They were all examined for good solder connections and checked for value prior to fitting.

New SMDs can be obtained from Maplin in 25-off minimum quantities or from other sources—they really aren't expensive but keeping costs down is in the authors blood and part of the fun of amateur radio. The circuit is laid out on a tiny PCB using ordinary glass fibre

Figure 1: 10GHz prescaler

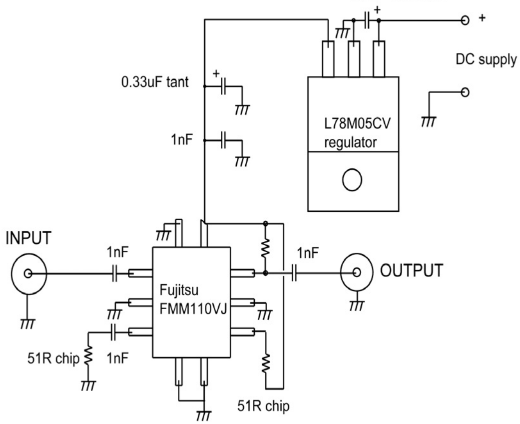
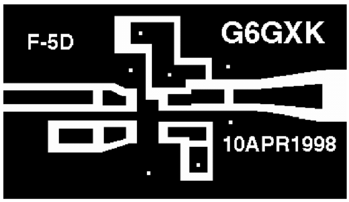


Figure 2: **PCB ARTWORK (ACTUAL BOARD LENGTH = 30mm)**



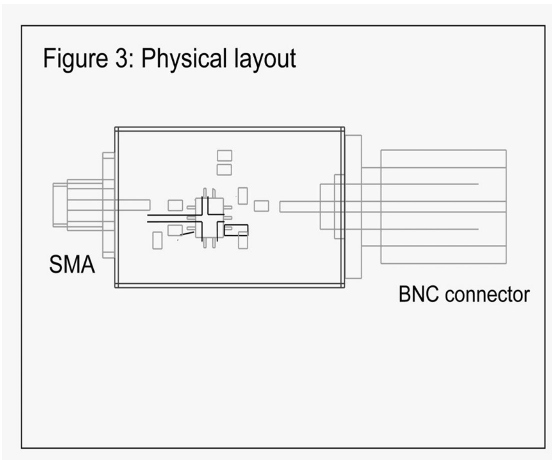


Figure 3: Physical layout

insulated, double sided, copper clad board about 1.5mm thick. The PCB layout is shown in figure 2 (actual length 30mm). The other side of the PCB is used as a ground plane and is almost all copper with only clearances being required for the 5 volt link and connection – these can be cleared with a drill – the ground plane is therefore not etched. It was decided to put in four link pins, using short lengths of wire to bond the earthy parts of the component side to the ground plane as in good microwave practice.

The overall assembly can be seen in figure 3 and is governed mainly by the size of the BNC connector to the frequency counter. The box was formed from 0.5mm tinplate. It was originally thought that the prescaler could have been fed with 5 volts from the frequency counter's internal battery powered regulator, which would have made a very convenient self-contained unit. However it was realised that the chip's requirement of 120-130mA would result in overloading of the internal regulator. A separate low dropout regulator the L4931CV50 was specified but was unobtainable at the time and a LM78M05CV was used instead.

This has worked just fine when supplied from a small PSU at any thing from 7 to 13 volts. It should be noted that the Fujitsu chip gets fairly hot when in use – it is dissipating around 0.65 Watts in that tiny case. For this reason and in order to obtain good grounding it is wise to ensure that it is soldered down to the PCB and that both sides of the PCB are soldered to the tinplate box. The regulator chip will also get hot, especially if it is fed from 10 volts or more, so it is best to mount it on the tinplate box. The prototype had its regulator bolted to a piece of tinplate soldered across the back of the box.

Construction

The PCB is small and simple enough to be cut with a modeller's knife, if an etching facility is not to hand. There should be nothing very critical about the tracks provided the basic layout is followed. Drilling the PCB was accomplished by hand using a 0.8mm PCB drill (ex-radio rally) mounted in the chuck of a pin vice. With a sharp drill this is a speedy process.

The author's eyesight is not as good as it used to be and he has found it necessary to use a headband mounted binocular magnifier to carry out fine work such as this. These are useful devices and are strongly recommended.

Since starting to construct microwave units the author has made himself a low electrostatic field assembly area which consists of a sheet of 0.5mm tinplate over the working surface, with wires soldered to it, to the grounding point of a low voltage temperature controlled soldering iron and to a wrist strap. This was used to assemble the unit and has been used successfully in the past to assemble discrete GaAs FET devices. Of course, modern IC's are tremendously robust but it isn't wise to take unnecessary risks.

Mounting the Fujitsu Integrated Circuit

The first component to be mounted onto the PCB was the IC package. It should be noted that the Fujitsu IC package is very small and the connections are very close to adjacent connections and also to the case, which is ground. It is very easy to bridge these connections with solder, or by poor alignment to the wrong part of the PCB, either of which would of course prevent the chip from working. The important points are:-

• Mount the PCB in a small vice or other holding device to keep it steady.

• Try the IC in place and make sure that the IC connections, which go under the IC package, are clear of other tracks.
• Tin both the underside of the IC package and the PCB area and connections leaving the minimum of solder on the PCB. Use solder wick to remove any excess.
• Use a clean finely pointed temperature controlled soldering iron with the minimum of solder on the tip.
• Hold the IC in place with tweezers, carefully aligning all the pins and gently dab one of the ground pins to attach it to the pcb at its tip. You will find the top left one is the most convenient in the long run. This will locate the IC, minimise misalignment and provide sufficient flexibility to enable the underside of its body to be soldered down.
• Hold the iron close to the chip touching the PCB and the two ground pins which are together at the bottom of the IC so that the heat will melt the solder under the chip.

Press it down with tweezers when the solder is melted and hold for a few seconds until set. It is important that the IC doesn't move out of alignment during this part. The pin connections can now be completed using very fine cored solder wire and with the iron away from the IC to avoid bridging. Use solder wick to clear away excess solder if things go wrong.

After successfully mounting the Fujitsu IC, the rest of the components can be mounted, along with the wire links.

Sourcing the tinplate

Making a tinplate box is fairly straightforward once you have the tinplate. Getting tinplate in Manchester is not so simple. Some tinplate was required to complete another microwave project. After ringing all round the local stockholders with no success, desperation set in and the thickness of old one gallon oil cans was checked – 0.22mm – too thin. So British Steel HQ in London were contacted who, through their Manufacturing Division in South Wales eventually located Lancaster & Winter in Bradford (Ref. 3). Success! So now some of this wonderful stuff was in the author's hands - every radio amateur constructor should have some in stock. Firstly it's much cheaper than brass, it solders beautifully, it can be cut without distortion with my wife's kitchen scissors (but only whilst she's not watching!). It makes good, rigid boxes to any size your heart desires. It not only provides electrostatic shielding - the steel in it also provides magnetic shielding.

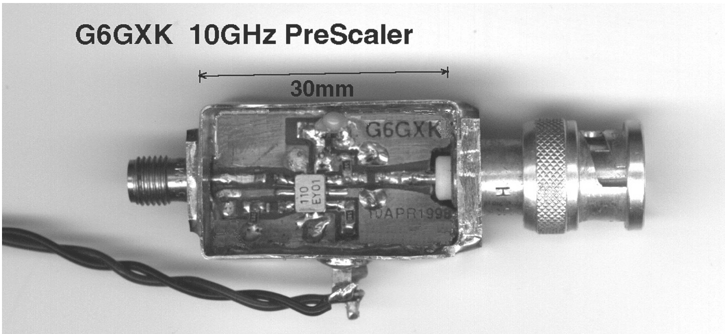
Completing the assembly

The DC supply is fed through a 1nF feed-through capacitor soldered into the tinplate wall. Alongside this the return lead is soldered to a bent up 6BA solder tag, soldered to the tinplate wall. At the back of the PCB the regulator was bolted with cut down leads (4mm) to a piece of tinplate which was soldered across the box so that the leads of the regulator were close to the feed-through can and the 5 volt connection to the PCB. It is important to fit the 0.1uF capacitor across the input to the regulator – otherwise it may oscillate. It was soldered directly across the regulator leads. The output of the regulator goes to the 5 volt input and this is then linked across the back of the PCB to the other 5 volt point.

Testing

The unit is very easy to test. Firstly, spend some time visually checking the soldered connections.

Apply power and check current consumption (about 130 mA). With no input there will be a high level of output at about 870 MHz. This is because the chip oscillates when not driven and this is normal - just remember that if



you think that you are seeing 6GHz or so it may be because the output has fallen to too low a level to trigger the prescaler. Find a source of RF at a level of about 1mW and frequency of 800MHz or more. Apply this to the input and check the counter. It should work without any problem, giving a reading of one eighth of the input frequency. It should also be checked using a 10GHz source such as a Gunn diode. For measurements like this, one useful technique is to use an SMA to waveguide transition and then to a small die cast horn. This can then be pointed at the end of a waveguide or at a horn feed and adjusted until a good steady reading is obtained.

Conclusions

Overall it has been a very satisfying project which continues to prove its worth on a daily basis. As Lord Kelvin is reputed to have said "If you can't measure it then you can know nothing about it!." Modern versions tend to be more forthright. Two prototypes have been built so far with a third one in process. No problems have been experienced in their operation. There are some limitations and possible improvements:

1. It needs to remembered that a strong reading of about 870MHz (6900MHz) will most likely be a "no signal" or "low signal" input condition. As the signal falls off the effect is to move fairly quickly to the 870MHz condition but it doesn't jump there.
2. You need a calculator to multiply the result by 8, not quite as convenient as a direct reading device. There is no easy solution unless the counter you use has provision for prescaler multiples to be input. Any other solution would either require extensive modification to the counter or a worsened resolution.
3. The power input limitations could be improved by using an input buffer amplifier which could both improve sensitivity and provide some limiting against higher powers. Perhaps two opposing diodes across the input would provide some protection against possible overload as available power levels increase.

References:

Ref .1: A 12GHZ Prescaler 1:8.by Angel Vilaseca, HB9SLV and Serge Riviere, F1JSR, DUBUS TECHNIK IV 1995.

Ref. 2: Fujitsu Microelectronics Ltd, Compound Semiconductor Division, Network House, Norreys Drive, Maidenhead, Berkshire, SL6 4FJ. Tel 01628 504800, Fax: 01628 504888.

Ref. 3: Source of 0.5mm tinplate sheets approx 860mm by 800mm about £5.00 each (as at June 98): Lancaster & Winter Ltd , Steel Stockholders, Bradford, West Yorkshire,
BD8 9AE, Tel: 01274 498454

A 10GHz Divide-by-10 Prescaler

Grant Hodgson, G8UBN

Introduction
A prescaler is a digital frequency divider; the output signal is simply the input signal divided by an integer (i.e. a whole number). Prescalers are digital devices and therefore the amplitude of the output is constant and bears no resemblance to the amplitude of the input signal.

Prescalers have two main functions for amateur microwave use: to extend the range of frequency counters and for dividing the output of a Voltage Controlled Oscillator when used in a frequency synthesiser. This article will concentrate on the former application, although the same design can be used in the latter application as well.

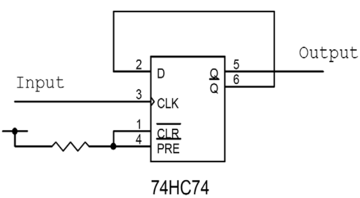
Digital Prescalers
Dividing the frequency of a signal by two is very easy; all that is required is a single D-type flip-flop (or latch) with the input signal being connected to the clock pin and the Q’ output being connected to the D input as shown in **figure 1**. The output signal is usually taken from the Q output.

Cascading prescalers (i.e. connecting them in series) is also easy; in this way it is possible to generate division ratios of 4,8,16 etc; division by 64 and 256 is very common. Prescalers operating at microwave frequencies are now commonplace; semiconductor manufacturers such as Fujitsu and Hittite have been making divide by 8 prescalers that can be used with input frequencies exceeding 10GHz for several years [1], [2].

Low cost frequency counters are now readily available that will operate at frequencies up to 1GHz or even 3GHz, the quality varies somewhat and generally speaking, you get what you pay for. However, microwave counters operating up to 10GHz or above are very expensive, even on the second-hand market, and are often difficult to find at all.

By combining a divide by 8 prescaler with a frequency counter operating up to (for example) 1.5GHz, it is possible to measure the frequency of a 10GHz signal, and possibly being usable to 12GHz. However, in order to determine the exact frequency of the device under test it is necessary to multiply the reading on the frequency counter by 8 - not too difficult if the counter reads 1.1101101, but multiplying a displayed number such as 1.2778563 is a little more complicated, usually requiring a calculator.

Flip flop used as divide by 2



New Divide by 10 prescaler
Thanks to some recent advances in high-speed digital electronics, the problem of multiplying the displayed frequency on the counter by a factor of 8 has been solved. Hittite Microwave Corporation [3] have recently (October 2002) released the HMC438 which is a revolutionary divide by 5 prescaler IC. This remarkable little IC requires only a single 5V supply and a couple of external capacitors to operate; the input

frequency extends from DC to 7GHz. The internal circuitry of a divide by 5 prescaler is a trivial task when working at low frequencies using standard CMOS techniques, but when working at microwave frequencies the number of individual transistors required to form the appropriate circuitry poses a number of technical problems, and the availability of the HMC438 marks a significant breakthrough.

Hittite also make a divide by 2 prescaler which operates from DC to 11GHz; cascading these devices results in a true divide by 10 prescaler that can be used up to at least 10GHz and beyond. The full circuit diagram is shown in **figure 2.**

All three ICs are powered from a single +5V supply, and a 5V regulator is fitted to the PCB but not shown on the schematic for clarity. This allows the prescaler to be used with a standard 12 – 13.8V DC supply, and gives some protection against accidental polarity reversal.

The input signal is DC blocked by the capacitor C1. The value of this capacitor determines the sensitivity at both high and low input frequencies. Due to the fact that the prescaler is intended for high frequency operation, the value of the capacitor has been chosen to maximise the input sensitivity at higher frequencies.

The input signal is amplified by IC1. This is a Gali-1 MMIC (Monolithic Microwave Integrated Circuit) from Mini-Circuits. For input signals greater than approximately –10dBm this amplifier is driven into saturation, which ensures that the output level is constant. IC2 also provides a secondary function in the form of an input protection buffer; a large input signal will simply be limited by IC1, thus giving a constant level output signal. If an excessively large input signal is applied IC1 may be damaged, but this is much easier and cheaper to replace than IC2.

The level of the signal is then attenuated by the Pi-attenuator R1-R3. The signal level at the output of the attenuator is at a level of approximately -2dBm which is close to the optimum level for IC2. IC2 is the first prescaler which is an HMC361S8G. This divides the signal by a factor of 2.

The HMC361S8G has two balanced inputs; the attenuated signal from IC1 is connected to one input (pin 5) and the other input is connected to ground via the capacitor C12. The HMC361S8G also has two complementary outputs; again only one of which is used – the other is simply left open circuit. The divide-by 2 output at pin 3 is DC blocked and connected to one of the inputs of IC3, an HMC438 divide by 5 prescaler. As with IC2, there is an unused input which is grounded by a capacitor and an unused output which is left open circuit. The output of IC3 is at pin 7 which is DC blocked by C11; this output signal is exactly 1/10th of the input frequency and can be connected to any suitable frequency counter. The level of the output signal is approximately –1dBm.

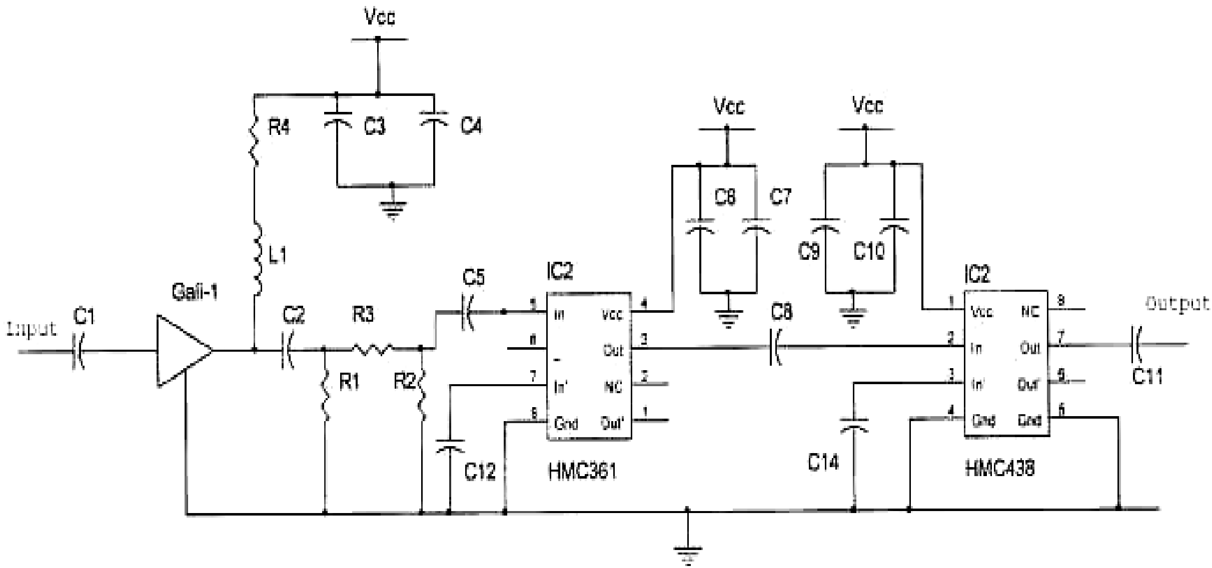
IC1-3 are connected to a single +5V supply; both prescaler ICs have two decoupling capacitors placed close to the VCC supply pins. L1 is a Mini-Circuits ADCH-80A broadband choke which provides a high inductive reactance from 50MHz to 10GHz – quite a remarkable performance in it's own right! R4 sets the current through IC1 to 25mA.

Construction

A PCB has been made for this project for those that feel confident to be able to solder the small devices. The PCB has provision for all the components including a 5V regulator and SMA 'end launch' sockets for the input and output. The PCB also has provision for a number of other features that will be briefly described later.

The biggest problem when trying to

Figure 2 – circuit diagram



build this particular project is soldering the prescaler ICs, and in particular the HMC438 which is very small indeed. Both the HMC361S8G and the HMC438 have a ground 'slug' on the underside of the package that cannot be seen when the IC has been soldered. The intention of the IC manufacturers is that these components are soldered using commercial SMD reflow techniques whereby solder is applied automatically in paste form, and melted in a special oven. These techniques are not suitable for small production runs, and the equipment required costs about as much as a small house. However, it is possible for advanced constructors to solder these devices at home, although some experience with small surface mounted components is required, as is some form of optical aid, a heat gun and some solder paste.

For best results the prescaler ICs are soldered first, one at a time. The technique involves placing a small amount of solder paste on the central ground pad on the PCB, and either applying a small amount of solder on each of the PCB pads for the IC pins, or applying the solder paste in a long line for pins 1-4 and 5-8. The prescaler IC is then very carefully placed onto the PCB, taking care to note the correct orientation. The IC will sit on top of the solder paste, and it helps if it is pushed down very slightly without twisting or moving it. The solder paste is then melted using a heat gun; the most suitable tool is a small, high wattage (> 1000W) gun used for heatshrink tubing with a small nozzle. Extreme care must be taken to ensure that the correct amount of heat is applied – too little heat and the solder paste will not have melted, which can lead to small solder balls which in turn can cause short circuits. Too much heat will damage the PCB and/or the IC. The right amount of heat will melt the solder paste properly, simultaneously soldering all 8 pins and the ground slug. As the heat is applied, several things happen :-

1) The solvents in the solder paste evaporate and the flux becomes active.

2) The solder on the pads for the IC pins melts. As this happens, the surface tension of the liquid solder pulls the IC on each of the 8 pins. If the solder on all 8 pins melts at approximately the same time, the IC will automatically be pulled to the exact centre of the pads – even if it was placed with a slight offset. The effect of this has to be seen to be believed – it really does look like magic, but is really just the application of physics!

3) As the solder melts, it naturally flows onto the exposed, tinned pads on the PCB, and so any paste that has been applied onto the areas covered by solder resist (the green coating on the PCB) will tend to flow towards the nearest exposed pad, thus automatically reducing the chances of a short circuit between adjacent pins.

4) At this point, the solder paste on the underside of the ground slug has not fully melted. It is necessary to keep the heat applied to the IC whilst the solder on the outer pins is still molten.

5) Then the IC will move slightly downwards as the solder under the IC melts and the surface tension pulls the IC further down onto the PCB. This is a very subtle effect, but can be seen with some experience and especially with good optical aid such as a microscope.

6) At this point the heat is removed and the board is left to cool, and then the solder paste for the other prescaler can be applied and soldered as above.

There has been some considerable debate on the US Microwave reflector [4] recently about alternative methods of soldering devices such as the Hittite prescalers with the 'hidden' ground slug; alternatives to the use of a heat gun are to place the PCB on a hotplate at a temperature considerably greater than the melting point of solder, or to use a conductive epoxy to mount the prescaler ICs. The use of epoxy would be an option, but unlike solder paste is very difficult to obtain in very small (i.e. cost-effective) quantities, and requires special care when curing, so it is felt that the use of solder paste would be the best option for home construction.

Note that the HMC438 is considerably smaller than the HMC361S8G – the HMC438 has pins on a pitch of only 0.65mm – that is the distance between the centre of the pins, not the gap between them! Although very small, this is an industry standard package, and is widely used for many ICs – especially microwave ICs. The use of good optical aid is mandatory; there has been discussion of this recently both on the US microwave reflector and in Technical Topics in Radcom.

Some of the RF coupling and decoupling devices are also very small, being of 0603 size – i.e. 1.5mm long x 0.75mm wide. These components can be soldered with a soldering iron with a small tip, fine solder (preferably 30SWG, although 26SWG can be used), optical aid and of course a steady hand! The reason for using such small capacitors is that they have a much lower self inductance, and therefore a higher self-resonant frequency. This means that higher values of capacitor can be used (4p7) for the high frequency part of the circuit, which increases the sensitivity at lower frequencies such as 4GHz. Therefore, smaller capacitors have the effect of increasing the effective frequency range over which the prescaler can be operated. It is fully appreciated that some microwave constructors will feel somewhat nervous about performing such delicate soldering techniques on tiny, expensive devices. For this reason the author is considering the option of making the PCB available with the ICs already soldered and tested, and possibly some of the other small surface mounted devices mounted as well. This would give a 'half-way house' whereby the hardest part of the construction has already been done, but the easier parts such as soldering the connectors and IC1, and mounting in a case would still be done by the constructor.

Printed Circuit Board

The PCB for this project requires special mention. It is made from 1.6mm FR4 (fibreglass), but instead of having the components on one side and a ground plane on the other, the PCB has 4 layers, with 2 ground planes sandwiched in the middle of the board. The reverse side of the PCB is thus free for extra circuitry, and has been used as a 'Microwave Experimenter's Project Board' which consists of pads for two Mini-Circuits Gali-MMICs, a passive, broadband frequency doubler, a SPST RF solid state switch and the possibility of a second frequency doubler. The use of a 4-layer PCB is believed to be unique in amateur microwaves. It has the advantage that although the RF properties of FR4 are inferior to Duroid and equivalents, the ground planes are only 0.3mm below the surface layers, which may allow the use of this type of board at 24GHz.

Of course the losses in the FR4 will preclude the use of this type of PCB for LNAs and PAs at such frequencies, but for other purposes such as doublers, mixers, filters and driver/buffer amplifiers this new 4-layer PCB technology may be usable at a much lower cost than Duroid, and can be manufactured commercially with plated through holes (vias) in very small quantities.

Any losses can easily be overcome with new high-frequency MMICs (such as the Galis), (at 10GHz or 12GHz) and 1.6mm
FR4 is considerably stronger than 0.25mm (or similar) PTFE material.

Performance

The maximum input frequency at which the prescaler will work is determined by a number of factors, including the gain of IC1, the loss associated with L1, the reactance of C1, C2 and C5 at frequencies above 10GHz and the upper frequency limit of IC1. In practice, the prescaler has been found to have an upper frequency limit of around 14GHz at an input level of +13dBm. IC2 has a specified maximum frequency of 11GHz, so this extra performance should be considered a bonus and cannot be guaranteed. For use at 10.4GHz, the minimum input level is approximately –15dBm, which makes the prescaler very sensitive. The maximum input level is 15dBm which is the absolute maximum input power for the Gali-1 MMIC. The prescaler has a definite cut off point; when the input signal is even very slightly above the maximum operating frequency the prescaler simply stops working and the output becomes unstable. Therefore it is very evident whether or not the prescaler is working properly. Note that this is usually not the case with a frequency
counter, where the counter usually starts to display a frequency slightly less than the true input signal. Also note that when no signal is present a the prescaler input, the prescaler becomes highly unstable and oscillates. However, unlike the Fujitsu divide by 8 prescaler (which oscillates at a fairly constant frequency with no input signal), the Hittite prescalers seem to produce a number of spectral lines which cannot be resolved by some frequency counters, although the may be harmonics of the fundamental oscillating frequency. This instability is to be expected, and is believed to be caused by the positive feedback action of the input circuitry which tries to 'capture' the input (sine wave) signal. With no input signal present, the input circuitry of the prescaler is trying to capture noise and becomes unstable. However, as soon as an input signal of sufficient level is present, all signs of instability disappear and the prescaler behaves normally. The DC current drawn by the prescaler does not increase in the unstable (no input signal) state.

Options

It is fully appreciated that this is not a cheap project, although it is felt to give reasonable value for money considering the high performance and the use of the newest prescaler technology. For those that want a 10GHz prescaler at a lower cost, IC2 can be replaced with an HMC363S8G divide by 8 prescaler IC, IC3 and associated components are not fitted and the output from IC2 routed directly to the output socket.

For an even higher frequency prescaler, IC2 can be replaced with an HMC364S8G which is a divide by 2 prescaler identical to the HMC361S8G, but with an upper frequency limit of at least 13GHz, and may be useable well beyond that, although this has not yet been tested.

For more sensitivity at 10 or 12GHz, IC1 could be replaced with a Gali-19 or Gali-19 high frequency MMIC; the author is currently testing this option.

Parts List

C1,2,5,12	4p7
C3, 11	100pF
C4, 6, 9	10nF
C7, 10	10uF Tant
C8,14	10pF
R1, 2	220R
R3	22R
IC1	Gali-1
IC2	HMC361S8G
IC3	HMC438

References

[1] 12GHz Prescaler, David Wrigley G6GXK, CQ-TV 185 (published by the British Amateur Television Club)
[2] New 12GHz Prescaler using Hittite HMC363S8G, David Wrigley G6GXK, www.microwave.fsnet.co.uk/projects/projects-1.htm
[3] www.hittite.com
[4] www.wa1mba.org/reflect.htm

Circular Waveguide - the Truth!

Richard T. Nadle, K2RIW

Editor's comment: *This article was written in 1999 after a series of practical experiments undertaken by Dick and his friends on Long Island. It appeared in print in the North Texas Microwave Society newsletter "Feed Point" in August 1999 and was also disseminated among those subscribing to WA1MBA's internet microwave reflector. Our thanks go to Dick for giving us permission to reprint this most interesting information. The 3/4" pipe Dick used in these experiments is available over here as 22mm (19mm internal diameter) copper pipe.*

1. INTRODUCTION -- I've received 8 e-mails, with some nice words of encouragement, about circular waveguide. There seems to be a thirst for knowledge on this subject -- the "poor man's" high performance WG. Some people wanted the extra decimal places and some wanted more description of the 10GHz 3/4" copper pipe experiments of "The Ten-X Group" on Long Island. In 1997 we burned a lot of "midnight oil" at the QTHs of N2LIV (Bruce, the president) and N2NKJ (Ron) while performing the pipe WG experiments. On the fourth night in three weeks, we again ended our experiments (with blood shot eyes!) as the sun was rising; we then knew we were pretty serious, or a little crazy, and that circular waveguide was great stuff. It was the Shepherd's Crook Dish Feed assembly of the San Bernardino Microwave Society (WA6EXV design, I believe) that got us started in the experiments.

At first, there were a few East Coast microwavers who thought the 3/4" copper pipe WG feed assembly, with four elbows, would have high loss .... we found that it actually has about as low a loss as you can get.

2. CIRCULAR WG FREQUENCIES -- If a 3/4" water pipe had exactly 0.7500 inch inside diameter, it would support the TE11 circular mode (the dominant mode) between the absolute min/max frequencies of 9.225 GHz and 12.045 GHz.
(The UK's 19 mm ID pipe will have cut off frequencies of 9.25 and 12.08 GHz .... editor)
Here are the first 6 cut-off, "absolute" frequencies (no guard bands) for 0.7500" ID pipe:

Frequency (GHz)	Mode(s), Circular
9.225 to 12.045	TE11
12.045 to 15.301	TM01
15.301 to 19.192	TE21
19.192 to 21.053	TE01 & TM11
21.053 to 28.002	TE31
Above 28.002	TM21

Some day I'll explain where all the extra digits are coming from. We've devised a way of getting Bessel functions to 12 decimal places; I was on a project that needed that.

3. FREQUENCY SCALING -- Once you know the ID of your "pipe", you can scale all these frequencies. So-called 3/4" water pipe comes in K, L, and M styles where each has a different wall thickness and slightly different ID. There are also multiple kinds of soft copper pipe, as well as some corrugated pipes, that will make great "semi-rigid" waveguide that can be bent around corners. You can measure the exact ID of your pipe with callipers and inversely scale all the above frequencies accordingly (bigger diameter is a lower frequency for each mode). If you intentionally deform the soft copper pipe with a good roller mechanism, you will make "poor man's Ellipto-flex".

Ellipto-flex has a very slight loss increase (for the same circumference) but it forces a particular polarization, and has a slightly wider frequency range for the dominant mode …. More on ellipto-flex at another time.

The mathematics called Bessel functions predict FM modulation and circular WG characteristics. Most of the books on circular WG are not very clear. One kind of Bessel function, of multiple sets, predicts the TM circular modes and the other kind of derivative Bessel, of multiple sets, predicts the TE circular modes. There's got to be a better way that "they" (or we) can explain all this.

4A. BOOK #1 -- The best reference I've found on the subject (I had to read the circular WG section ~ 10 times) is Theodore Moreno's "Microwave Transmission Design Data", Dover Publications, 1948 (original), 1958 reprint, available for $8.00 at ABEbooks.com.

4B. BOOK #2 -- Concerning WG components, here's THE BOOK: George Southworth, "Principles and Applications of Waveguide Transmission", D. Van Nostrand Co., 1950; 689 pages (an oldie but goody). It contains some of the best PICTURES of how rectangular and circular WG really works with lots of performance curves (you won't need the math to understand the pictures (pages 166 & 169), it's almost an animation) -- amazing stuff for 1950. Page 121 (A & B) has pictures are 21 of the circular WG modes (with the relative sizes of pipe shown, same frequency) made with an "RF absorbing camera". The book shows some great transition devices, hybrids, mode killing devices & devices for launching higher modes (pages 354 to 362), round WG components (pages 269, 327 & 328), circular guide fin line (page 133), a great section explaining choke flanges (page 201), a circular pipe polarization rotating device that's "home brewable" (page 207), the shapes of circular and rectangular WG (of constant periphery) that give minimum loss (page 193)(the popular ones are not optimum), "skeleton WG" (page 175), about 15 kinds of WG irises (page 246 & 255), circular WG filters (page 307), the Qualcomm duplexing filter explained (page 309); linear, binomial, Gaussian, and exponential WG impedance stepping functions for broadband impedance matching (pages 269 to 276), 14 designs for dummy loads (pages 368 to 371), about 25 attenuator designs, rotary vane phase shifter (page 333), rotary vane attenuators defined (page 375), a way of designing a variable conductance dissipative film (page 377), 33 pages of horn data (only portions have appeared in other WG or antenna books), 8 kinds of "backfire" feeds including the Cutler (pages 448 to 454), eight types of WG slot antennas (pages 425 & 430), five kinds of corner reflectors, waveguide lens antennas, some TWT and magnetron info, etc. The picture on page 186 shows me how I could make S-band waveguide out of rain gutter down spout tubing. Let a Microwaver stand in a good hardware store with that book in hand and I think he'll get some great and crafty microwave ideas!

5. SAME WAVEGUIDE MODES -- It is interesting to note that the main pipe WG mode, TE11 circular, and the main rectangular WG mode, TE10 rectangular, are the exact same mode. They use a different definition of the subscripts for circular and rectangular that makes them look different but they're not. Once we realize this it becomes easy to construct (HOME BREW!) devices that transition from rectangular to circular. We of the Long Island "Ten-X Group" of microwavers did a fair number of experiments in this area a few ago. Here are some of the results.

6. RECTANGULAR TO CIRCULAR TRANSITIONS -- Our "Elegant Transition" was a carefully constructed slow transition (over a 1 foot length) from rectangular to circular. It had an S11 of -35 dB (VSWR = 1.04). A "sloppy transition" was made by crushing one end of a 3/4" copper pipe in a vice and forcing it into a WR-90 WG flange *(WG16 flange in the UK ..editor)*. It had an S11 of -23 dB (VSWR = 1.15). To make these measurements we used a Super WR-90 (UK WG16) 20 dB coupler (50 dB of directivity)

7. DUMMY LOADS -- In circular WG, these are quite easy to construct. Simply sharpen a 3/4" broom stick handle and force it into the 3/4" copper pipe. About 3" of taper and 2" of non-taper is fine. The usual moisture in the wood makes a great "slow absorber", which makes it more forgiving of errors. The main difference between a -35 dB S11 dummy load (VSWR = 1.04, [sharp tip]) and a -20 dB S11 (VSWR = 1.22) seems to be how sharp the point was at the tip of the broom stick handle and was the taper too abrupt (too short). There may be some variations caused by knots in the wood, but we didn't seem to have that problem.

The completed circular WG dummy load consists of a ~ 7" piece of 3/4" pipe with the tapered broom stick handle (absorber) in it plus a copper pipe coupler at the open end. Some of the broom stick absorber can stick out the pipe far end, if you prefer. It is easy to place this load on any other piece of circular WG, while running component tests. These pipe couplers really are "sexless" connectors. For experienced rectangular WG users, it will feel strange to make connections in 2 seconds and not worry about screwing down the flanges to get a good VSWR!

8. LAUNCHERS -- A circular WG to SMA launcher consisted of a 3/4" copper pipe end cap, soldered onto ~ 1.5" length of 3/4" copper pipe and an SMA Female to Female (bullet) is fed through a hole in the side of the end cap plus pipe, ~ 1/4 wave away from the closed end (it is either threaded into the end cap and use a nut, or simply solder it). A ~ 1/4 wave long wire probe inside does the launching. A pipe coupler is slipped over the 1.5" length of pipe that protrudes. The completed launcher can be placed on any piece of circular WG in 2 seconds by the "sexless" connector (pipe coupling) method.

Proper adjustment of the position, tilt (forward and aft), and length of the probe wire is a bit tedious. Place a circular WG load on the launcher output and measure the VSWR at the SMA connector to find the proper probe length; it's an unambiguous operation. Once you get the hang of it you will make quite a number of launchers at once. The one component of the launcher that costs anything is the SMA bullet.

9. PADS -- We never did this but it would be easy to design circular WG fixed attenuators by decreasing the length of broom stick absorber and tapering both ends to have a good impedance match from either direction. In this case I would recommend painting the absorber to keep the moisture content (absorption) constant. If it is found that the loss is too great for a convenient length of tapered wood absorber, consider making the absorber out of six "splines" by using thin sheets of wood, or out of balsa wood. These low density materials (with tapered ends) will allow a lower insertion loss to be constructed from a longer length of wood absorber. Also, the slower loss characteristic will cause a lower VSWR for a particular taper rate.

10. COUPLER (SEXLESS CONNECTOR) -- There is a kind of copper pipe coupler that has no internal ridges or dimples. These will allow the 3/4" pipes to directly touch(butt against each other inside the coupler) without any gap. A gap will have a larger inside diameter, within the coupler. Even with a gap, the VSWR impact was very small. If these couplers are unavailable, a purist can remove the ridges or dimples with a round file or an adjustable reaming tool. However, you will find that the moulded copper fittings are hardened and the reaming/filing operation is a quite difficult.

11. OTHER COMPONENTS -- We discovered that many of the hardware store 3/4" plumbing fittings were almost "designed" for us microwavers. A 45 degree elbow and a 90 degree elbow gave us VSWRs of ~ 1.3 and 1.4, as I remember. The copper pipe "coupler" makes a great trombone and polarization twister. The end caps are a great way of constructing 3/4" circular WG to SMA launchers. When the circular WG components are properly plugged together with these "sexless" connectors, we haven't found any fittings that change significantly in VSWR as you do or do not solder them.

Test everything by plugging them together, solder them later. Soldering seems to only be required for mechanical reasons.

You will find that many circular WG components are **VSWR sensitive to rotation** (at the sexless connectors). Many circular WG objects can create elliptical polarization. Southworth's book covers this subject on page 206. A liberal sprinkling of septums within launchers, horns, etc. will force a linear polarization at the output point (usually without loss) and they insure that the elbows and other non-symmetric components don't create elliptical polarization. A septum consists of a thin sheet of metal soldered across the diameter of the circular WG at right angles to the desired polarization.

A screw protruding into the guide makes a great way of correcting VSWR; however, depending on its polarization, it could also create some elliptical polarization -- so use a septum in the vicinity of the circular WG output. Find the best location for the screw by using a steel BB inside the WG and positioning it with a magnet on the outside.

Copper transitions from 3/4" to 1" and 3/4" to 1.5" make nice feed horns. A 3/4" soldered-pipe to threaded-pipe adapter makes a convenient flange for the centre of a dish antenna. That's where you feed the Shepherd's Crook 3/4" circular WG through the dish. Two large washers and a large nut can hold this assembly in the dish centre. It is also possible to mount a copper 4 hole flange to the back of the dish centre and feed the round WG through it. In each of these cases it will be necessary to ream out the shoulder within the fitting to allow the 3/4" pipe to pass through the fitting. We purchased a mechanically adjustable ream to accomplish this. The operation was quite difficult because of the hardening of the moulded fittings. With a lathe this operation was a lot easier, when there was enough metal to mount in the lathe chuck.

12. WG POLARIZATION -- I must give you a warning! If you are using a long length of pipe as WG up your tower (K2TXB and W2DRZ did this), the ellipticity of the pipe (the "run out") could cause a horizontal polarization, launched at the bottom, to become a vertical polarization at the top of the tower (the polarization can rotate). By simply rotating the launchers at the top and bottom of the WG, you will find the lowest loss combination for that "pipe WG"
There is also this added danger ... when you are in your Home Depot Hardware Store, with your callipers, while buying 10' lengths of pipe that

have no run out, you will find the following … one pipe in 3 has almost no run out, that's the ones you want to buy; (2) The Plumbing Department Foreman will watch you during this process and he will say, "Oh no, another one of those crazy engineers who's doing a precision plumbing job in his house!" You will have to suffer some ridicule in the pursuit of your art. You probably will not succeed in explaining what you are really doing, just remember -- you're tough and can take this ridicule, you are pursuing a far off goal, that great 3cm DX!

13. CIRCULAR WG DISH FEEDS -- For a 0.6 F/D dish, the W2IMU Dick Turrin dual mode horn intentionally launches the TE11 and TM11 circular modes at just the right amplitude ratio and relative phase. That's what gives it such a beautiful pattern ... No edge currents, no side lobes and great control of the electronic phase centre versus azimuth, elevation, or diagonal scans. Any shift in the electronic phase centre of a horn versus observation angle creates the same antenna pattern degradation as if you had the same amount of error (like a big dent) in that area of the parabolic reflector it is illuminating. With this understanding, it becomes more obvious why this horn achieves higher dish efficiency. For deeper dishes (~ 0.3 F/D) the Scalar feed (the one with the multiple rings) does almost the same job.

But, be careful. The W2IMU multimode circular horn can get a Microwaver involved in an altercation or a law suit. I constructed my 2287.5 MHz W2IMU horn from food cans for Apollo 15 and 16 reception "Houston This is Apollo" (QST June 1972) and "A 12 Foot Stressed Parabolic Dish Antenna" (QST August 1972). I measured the diameter of all the food cans in the local super market. The store manager became alarmed. and asked me to leave. He thought I was a Ralph Nader advocate and was about to start a litigation (I had to endure ridicule way back then too). I settled on Scotts Oatmeal cans, purchased from a Foods of All Nations Store; they had the correct diameter for the launcher and RHC polarization section.

14. CONCLUSION -- I hope you all enjoy the above info. There are a few more 10.368 GHz 3/4" copper pipe experiments to be described later. Please feel free to correct the errors or add to the info.

Making more Flexible 90 degree twists in Waveguide

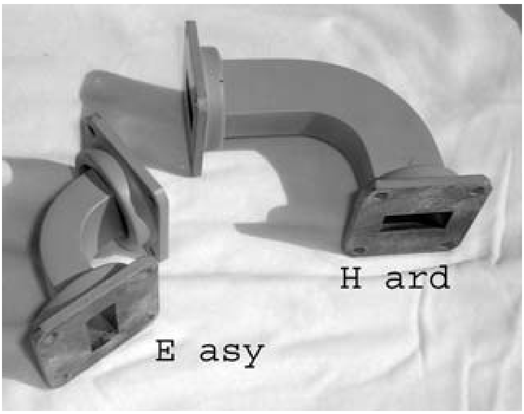
Kent Britain, WA5VJB

Getting waveguide to go around a rotator, or even to be flexible going up a portable mast, can be fun.

Waveguide has E and H planes. One way to remember which is which, is it to think of these planes as H hard and Easy to bend.

You could easily bend waveguide along the Easy Plane, but it's a lot Harder to bend it along the H bend. It's that Easy and Hard planes that make it fun to get even the 'Flex' guides to twist. They bend easy one way, but not the other.

When it come to E and H bends in waveguide, just look at it and think which would be easier to bend, that's the E bend. Keep an eye out for 90 deg waveguide twists. Using two short sections of flexiguide with a 90 deg twist in the middle makes the whole section much more flexible.



Got the Connection?

Richard T. Nadle, K2RIW

Concerning microwave connectors, the story goes ….

N is for Neil, **C** is for Councilman. Those are the connector names.

BNC is Bayonet Neil Councilman, **TNC** is Threaded Neil Councilman.

Likewise, I was told **SMA** was Sub Miniature type "A". **SMB** was Sub Miniature type "B" and **SMC** was Sub Miniature type "C", all originally Bendix names (they invented the SMA).

I did not originate this story; I got it from an older issue of the "Cheese Bits", the monthly journal of the Mount Airy VHF Radio Club (The Pack Rats), from the Philadelphia, PA area. I've repeated the story to many RF people and have encountered older engineers who remember the creation of those connectors. Sometimes they confirm the story, so it might be true.

Most people who served in the US Navy have been told that the N Connector stands for Navy Connector, instead of the Paul Neill Connector. I've worked in the RF and Microwave world for over 35 years. RF people use coaxial connectors every day and almost every other day they hear the word RADAR. To me it's amazing that most engineers never ask what these abbreviations stand for. When you tell them, they are amazed that the letters really stand for something, as apposed to being randomly chosen letters such as C Band, S Band, or V Band.

Here is a way you can have some fun with your fellow engineers. Just ask them what do the letters stand for in N, C, BNC, TNC, SMA, SC, HN, RADAR, or SONAR. You will probably find that less than one engineer in 10 knows what ANY of those abbreviations stand for, regardless of their years of experience.

I've run that experiment at AIL, Kmec, Rockwell, Northrup, Sanders, Cutler Hammer, MPD, Narda, Telephonics, Bell Labs, Johns Hopkins APL, Edwards AFB, Wright Paterson AFB, Eglin AFB, NASA Goldstone, NASA Goddard, NASA Kennedy, NASA Johnson, China Lake NAWC, Pt. Mugu NAWC, Johnstown NAWC, Rome ADC, Bell Northern Research (Canada), Westinghouse, Comtech, Bendix, Lockheed Martin, AEL, IBM, Microwave Associates, Amplica, HP, Agilent, Avantek, Mitec, Eaton, EDO, and a few more! The ratio is always the same and the amazement of the engineers is always the same. The information seems to be a well kept secret and I wonder how it happened.

I'm saddened that the engineers who created these great connectors are such unsung heroes. There are companies (such as AIL) where almost every product, for the last 55 years, has something to do with RADAR -- Receivers, Transmitters, Exciters, Jammers, Antennas, Direction Finders, Surveillance, Reconnaissance, Diplexers, DSP, Range Doppler Matrix, Pulse Forming Networks, Rotary Joints, Pulse Compression Networks, Synthetic Aperture RADAR (SAR), Inverse SAR, TWTs, HPAs, LNAs, etc. Choose an engineer who has worked there for 20 years (or any other number) and tell him the following: "RADAR has put food on your table for the last 20 years, it's one of the most important words in your vocabulary; what does it stand for?" You will see him struggle to find a word for the first A in RADAR

-- there isn't one, it's not a real acronym. RADAR is a contraction that stands for RAdio Detection And Ranging -- according to Skolnik, "Introduction to Radar Systems", 1962, page 1. While he is struggling to come up with the definition I will say, "you know, Pete in the Transmitter Department knows RADAR so well that he can even spell it backwards". I once asked that question of 15 engineers at a RADAR savvy company before getting the correct answer. It was the 5th engineer in the RADAR Department who knew the answer!

Before you try any of these tricks on your fellow workers, be sure you have chosen someone who likes you and has a reasonable sense of humour. Some people take themselves so seriously that they can't stand to have any of their weaknesses exposed without blaming you, the exposer.

Have fun with this information but be careful -- there is a mine field out there of people who can't take a joke concerning their profession. We all make mistakes, and we all have missing pieces of information -- try to enjoy the educational process. If you can't laugh at yourself, you're probably taking things too seriously and living a much harder life than you have to. Mother Nature didn't make this RF Universe in such a way that it's easy for anyone to really understand a whole lot of it. It's probably that challenge that got most us into the Microwave business/hobby in the first place.

By the way, that beautiful little (~ 2mm) push-on RF connector that's located on your Wireless LAN Card (it's a closed-circuit jack intended for an external antenna) is an **MMCX** Connector (Micro-Mate C). There are different companies that sell a gold plated SMA to MMCX (Male) adapter for prices that range from about $8.00 to about $60.00 each. The quality seems to be the same. There are experimenters that have gotten miles of 802.11b DX with an external 2.4 GHz Dish antenna connected to their barefoot Wireless LAN Card.

RF Cables and Connectors Don't Get Any Respect … But They Should!

From an abridged article by Jim Pomager, Editor-in-Chief RF Globalnet

Editor's note: *Our thanks go to* ***Jim Pomager, Editor in Chief at RF Globalnet*** *for giving permission to use his article.*

Unlike active devices such as ICs, cables and connectors are quite possibly the most unglamorous components in the RF/microwave design world. Like doorknobs in an architectural plan, RF cables and interconnects are rarely considered during the design process itself. Rather, these necessary evils are typically contemplated only after a project is all but complete.

They truly don't get much respect. However, these oft-neglected components can have a significant impact on overall system performance. In the commercial field, RF and microwave design engineers face enormous pressure to deliver quality products at lower costs. As a result, cable and connector vendors can end up being their best friends, helping them meet a variety of electrical, mechanical, and environmental demands. In fact, today's cable and connector suppliers are supporting designers with products that are smaller, faster, and more phase stable than ever before. Microminiaturized products handle higher frequencies, conserve space

There are two key factors behind the continuing reduction in RF cable and connector sizes. First, the frequency ranges of RF/microwave systems have been creeping steadily higher
(driven principally by the need for higher data rates in communication systems) and small diameter coaxial cables are generally more efficient at carrying the higher microwave frequencies than are large-diameter cables. Hence, we have witnessed the rise of small-diameter, high frequency cable -- and the microminiature connector. One line of connectors that illustrates this trend toward higher frequency and smaller size is the MMPX series from Huber+Suhner. These board-mount, microminiature, snap-on connectors are comparable in size to the diminutive MMCX connector and are compatible with the MMCX interface. They demonstrate linear VSWR at frequencies from DC to 65 GHz and have shielding effectiveness of -85 dB from DC to 26.5 GHz, -65 dB from 26.5 to 50 GHz, and -60 dB from 50 to 65 GHz. Applications include test and measurement, defence, and mobile radio. MMPX connectors are available in straight cable plug, straight cable jack, right angle cable plug, straight PCB jack, edge-mount, PCB jack, and adaptor configurations.

For more information, visit **www.hubersuhner.com**.
Tensolite brings its SMP and SSMP lines of blind-mate push-on connectors to the microminiature party. The SMP series covers DC to 40 GHz and

permits connector spacing as close as .170 inches for an assortment of military, space, and telecommunications applications.

The SSMP series ratchets it up a notch in frequency (to 65 GHz) and down a notch in size (spacing to .130 inches) for smaller, lighter systems. SSMPs are offered in popular interconnection versions for cable assemblies, surface launch, edge launch, hermetics, adapters, and loads. For more information, you can download Tensolite's RF/Microwave Products Catalogue from their website at

www.tensolite.com

The second major factor influencing RF cable and connector size is the shrinking of the RF/ microwave system itself. With almost all package sizes getting smaller. As a result, cables and interconnects (all components, for that matter) must have minimal footprints, whether they are on a board, in a base station, or on a tower.

Nowhere is this lack of space more evident than inside a wireless device. For this cramped environment, RF Industries introduced the MHF series of micro connectors and cable assemblies for Wi-Fi. These coaxial connectors have a mating height of 2.5 mm. They support dual-band applications in the 3 to 6 GHz range, including laptops, PDAs, and cell phones. Cable assemblies are available with a range of connectors, including SMA, MMCX,TNC, and Type N. For more information, visit

www.rfindustries.com

In the test and measurement arena, where cables are constantly being attached/detached from instrumentation, recent advances in interconnect technology can help save engineers a lot of time (and a little sanity). Winchester Electronics (USA) just released its QC-SMA series of SMA connectors, which cover the frequency range of DC to 6 GHz. These connectors incorporate a push/ pull style of mating, which allows them to be connected and disconnected without the need for special tooling. (This is in direct contrast to standard SMAs, which must be torqued for proper installation). Once QC-SMA connectors are mated, they can rotate 360 degrees without losing connection.

In addition to test environments, these connectors can also be used in microwave subsystems, base stations, mobile radios, and other applications. For more information, download the QC-SMA datasheet at:

www.winchesterelectronics.com/products/qc/qcsma.asp

Stainless steel connectors …. good or what?

Peter Blair, G3LTF

This may only be of interest to microwave EME people! Some days back I asked the following question.... "Does anyone out there have any real data on the difference in loss between a standard gold plated SMA connector and a stainless steel one at frequencies of 1296MHz and 2304 MHz. I have a built in prejudice against using them at these frequencies but it is only that, I don't have any data."

Chris,G4DGU, made the following sensible comment: "My qualitative view is that there's not a huge penalty - perhaps 0.02 - 0.05dB extra loss at 10GHz. My reasoning is that the centre conductor (which has the highest current density, of course) is gold-plated anyhow, and that losses in the outer are mitigated by the much lower current density. I've not seen any evidence of excessive temperature rise in a pair of mated s/s SMAs carrying 40W at 10.3GHz."

It proved difficult to find one for one comparisons and most SMAs are in fact stainless steel plated with gold. I found two manufacturers websites quoting figures for stainless steel gold plated of (0.03x square root of frequency in GHz) dB... but I couldn't find any figures that were clearly and definitely for non plated stainless steel. For comparison, 10cm of 0.141" coax is (0.038 x square root of the frequency in GHz) dB I found some other interesting data however.

A hermetically sealed connector is (0.05 x square root of the frequency in GHz) dB and brass SMA connectors are quoted as (0.06x square root of the frequency GHz) dB, clearly these are to be avoided. (If you can't tell the difference between brass and gold then try "Alchemist" in your Yellow Pages).

The Radiall website at **www.radiall.com/vdocportal/radiall.jsp**
(then follow SMA and Literature, page 11-12)...
has some interesting data . It quotes straight SMA connectors as 0.02dB flat from 1 to 10GHz (which doesn't seem right, it must vary as the square root of frequency) but quotes a right angle connector as 0.04dB at 1GHz, 0.05dB at 2.4 GHz and 0.09dB at 12.4 GHz. I suspect that much of this is a VSWR contribution but it would seem that a minimum length 0.141" cable with two straight connectors is a better solution than a right angle connector. Also in the Radiall data is a useful chart of power rating vs. frequency for SMA connectors.

Now you might think that none of this really matters but at 1296/2320MHz with a low noise dish and feed then, if you have a NF of 0.35dB, changing the loss in front of it from 0.1 to 0.2dB will worsen the receive sensitivity by 0.5dB (see VK3UM eme calc programme at: **web.telia.com/~u92010241download.htm**)

10GHz Losses in Connections between circuits

André Jamet,F9HX and Michel Métroz, F1EER

What's the problem ?
We need to have connections between circuits in the chain of a transmission-reception system, especially for the antenna. Their losses are very penalising as they can ruin the output power as well the actual receive sensitivity. Between intermediate circuits, it is less crucial since the losses can usually be compensated for. As the frequency is increased, interconnection losses are higher due to the increase in component losses. We have to take care to minimise interconnections lengths and to not use lousy components!

What arrangements do we have to do ?
At 10GHz and a fortiori, the rule above is to use wave guides as they have minimal losses as shown in **Table 1** which also gives losses for commonly used conductors and components, as well their SWRs.

The data is valid for **new/in good condition components** but is not generally the case for second hand ones. It's wise to invest in new connectors for the more critical connections in the same way as it is to use high quality capacitors (typically ATC ones) for the PA output and the preamplifier input.

If the connection to the parabolic feed is made by a wave guide and if we are lucky to get a waveguide relay, we will obtain the minimum of losses. If the PA and the preamplifier are also wave guide connected, we will get the best solution but if they are SMA connected we will need a transition to go the antenna wave guide.

If we do not have that kind of relay but only a coaxial one, we'll need SMA connectors to go to the PA and the preamplifier. In order to have a short connection we can use a straight coupler SMA-SMA. If we need a longer connection and angles we'll need a very good quality cable (for example a semi-rigid one) with two connectors. So that we have two routes, one for transmission and one for reception, we can compute the total losses from the individual components losses.

SWR effect
Standing waves are created by a lack of impedance matching between various circuits and by components themselves. When the SWR increases significantly the losses also increase, as shown in **Table 2.**

Moreover, we are not sure that the antenna, the PA and the preamplifier are well optimised to comply with a purely resistive 50 ohms impedance. Very often, the preamplifier requires a reactive source to get the weaker noise factor. That means a 3 to 1.5 SWR (return loss 6 to 14 dB). An advantage of the all wave guide connection is the chance to put independent matching screws in both transmission and reception routes so we can adjust them separately (which is impossible when the wave guide is common for both routes and in the case of coaxial connections). Of course it is essential to use very finely adjustable matching screws, without bad contacts and locked up in the best position.

Measurements
In order to verify data given by the manufacturers, some measurements were done at 10GHz on several components at our disposal. Loss measure-

Table 1

COMPONENT	DATA at 10 GHz
wave guide W90/R100 (copper)	-0.12dB/m SWR ≤1.03
semi-rigid coax .141 RG 402 Ø 3.58mm	-1.52dB/m SWR ≤1.04
SHF 3 cable	-1.88dB/m
RG 58	-1.50dB/m @ 3GHz
RG 174 / KX3 cable	-0.56dB/m @ 400MHz
SMA straight connector semi-rigid cable	-0.10dB SWR 1.15
SMA straight with flexible cable	-0.20dB SWR 1.20
SMA right angle with semi-rigid cable	-0.15dB SWR1.20
SMA right angle with flexible cable	-0.25dB SWR 1.35
relay SPDT with SMA females	≤0.40dB SWR ≤1.40 isolation ≥60 dB
relay SPDT in wave guide	-0.05dB SWR ≤1.10 isolation ≥70 dB
flange for W90 guide	-0.01dB
adapter guide/SMA f right angle	≤-1.10dB SWR ≤1.5
adapter guide/N female	-0.30dB SWR 1.15
straight coupler SMA m/m	-0.10dB SWR 1.05
straight coupler SMA f/f	-0.20dB SWR 1.1
right angle coupler SMA m/f	-0.25dB SWR 1.5
right angle coupler SMA f/f	-0.25dB SWR 1.7
transition wave guide/SMA f straight	-0.30dB SWR 1.15

ment was simply done with a 10GHz source and an 18GHz spectrum analyser (HP141T). The validity of the method was tested by the measurement of a 3 dB attenuator. Others measurements for losses and SWR were done with a vector analyser, ANRITSU 37269A, (40GHz) and some with a test bench equipped with a sweep oscillator (HP8350B) with a 2-18GHz HP 86290A, an 18GHz detector (HP11664) and an 18GHz SWR bridge (Wiltron 87A50-1).

The results are given in **Table 3.** In addition, curves for two SMA attenuators were drawn up to 40GHz. It

Table 2

SWR	losses in dB										
1	0.2	0.5	1	1.5	2	2.5	3	3.5	4	5	6
1.5	0.2	0.5	1	1.5	2.1	2.65	3.15	3.65	4.2	5.2	6.2
2	0.28	0.65	1.2	1.8	2.3	2.9	3.4	3.9	4.4	5.5	6.5
2.5	0.3	0.7	1.3	1.9	2.5	3	3.6	4.2	4.7	5.8	6.8
3	0.32	0.8	1.5	2.1	2.8	3.4	4	4.5	5.1	6.3	7.3
4	0.4	0.9	1.8	2.5	3.3	3.9	4.5	5.1	5.4	6.7	7.8
5	0.5	1.2	2.2	3	3.8	4.5	5	5.5	6.2	7.3	8.4
10	1.2	2	3.5	5	5.5	6.2	7	7.5	8.2	9.5	10.6

is obvious that, above 18GHz, losses and SWR grow rapidly and this is normal for this kind of connector.

EXAMPLE

Two examples of connections will show how we can lose decibels and QSOs !

First case: wave guide entirely

- connection feed, parabolic to SPDT relay: 10cm waveguide WR90 0.01dB flange 0.01dB
- SPDT wave guide relay 0.05dB
- connection to PA or preamplifier: 10 cm wave guide WR 90 0.01dB flange 0.01dB

total losses: **0.09dB**

Second case: SPDT SMA relay

- connection feed parabolic to relay: 10 cm wave guide WR90 0.01 dB
- adapter wave guide/SMA 0.30 dB
- SPDT SMA relay 0.40 dB
- connection to PA or preamplifier: 10 cm coaxial cable .141 0.20 dB

-**total losses: 1.21 dB**

The 1.12 dB difference between the above cases could be regarded as negligible but if we make an effort to afford a 0.7 dB noise factor preamplifier, home made or bought, we will have an 1.98 dB in the second case. During transmission, the difference should be to appear more negligible. However for a 10W PA (+40 dBm) we start from + 39.91 dBm to + 38.99 dBm that is to say 1.87W excess loss. In practice **it is certain that the coaxial connection case is worse than already calculated**. A high SWR will increases losses and the difference with the wave guide solution. The SWR of the SMA relay alone can reach 1.4. Moreover, if the SMA connectors are not tightened with a torque wrench, losses could be worse. Coaxial cables can be damaged if they are bent with too short a radius. So losses can be fatal in relation to a difficult QSO, especially in EME applications.

Conclusion

Microwave watts are very expensive (that it is currently known!) owing to the price of transistors. In reception, lowest noise factors are expensive too. So do not spill precious decibels because they make or break a possible QSO.

It is obvious that those remarks apply to other microwave bands than 10GHz, as the problem grows very fast when the frequency is increased.

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Appendix

The additional losses dues to the SWR is calculated (see ARRL HANDBOOK) by :

total losses for a line = 10 log (B2 – C2) / B (1 – C2)

where :

B = 10 (line loss in dB) / 10
C = (SWR – 1) / (SWR + 1)
SWR is that we can measure at the load, for example :

For a 2 dB line losses when the SWR = 1
if the SWR is reaching 5, we have :

B = 10 (2/10) = 1.585 et C= (5-1)/(5+1) = 0.6666 and :

losses with SWR = 5 : 10 log(1.5852– 0.6662) / (1.585 (1-0.6662)
= 3.74 dB

Table 3

COMPONENT	Measured at 10 GHz
straight coupler SMA m/m # 1	-0.07dB SWR 1.04
straight coupler SMA m/m # 2	-0.08dB SWR 1.1
straight coupler SMA m/f stain steel	-0.07dB SWR 1.02
straight coupler SMA m/f gilded brass	-0.06dB SWR 1.02
right angle coupler SMA f/f	-0.25dB SWR 1.45
Adapter guide/SMA f (homemade with SWR screws not adjusted)	-3.30dB SWR 1.48
As above (but screws adjusted)	-0.5dB
adapter wave guide/SMA f (on a side)	-0.28dB SWR 1.15
adapter wave guide/N f (at the end)	-0.27dB SWR 1.03
black flexible cable KX3/RG 174 325mm SMA m	-5.08dB SWR 1.86
As above but 192 mm -3dB brown flexible cable PTFE SR142B 500 mm Ø 5 mm with two SMA male	-0.85dB SWR 1.06
re-shapable cable .141 red braid 925 mm Suhner SUCOFORM 141 CUPE with right angle SMA m and SMA N f panel mount	-1.52dB SWR 1.12
Re-shapable.141 59,5 mm with SMA m and SMA m	-0.91dB SWR 1.07
conformable cable .085 237 mm with two SMA m	-0.70dB SWR 1.19
semi-rigid .141 6 bends 220 mm with SMA m, f	-0.32dB SWR 1.04
semi-rigid .085 (5 bends) 347 mm with SMA m, f	-0.82dB SWR 1.1
semi-rigid .085 (6 bends) 374 mm with SMA m, f	-0.92dB SWR 1.14
semi-rigid .141 65 mm with two SMA m	-0.50dB SWR 1.18
semi-rigid .141 72 mm with two SMA m	-0.12dB SWR 1.12
semi-rigid .141 273 mm with two SMA m	-0.41dB SWR 1.04
semi-rigid .141 120 mm ? shaped with two SMA m	-0.80dB SWR 1.09
semi-rigid .141 300 mm trombone shaped with right angle SMA m and right angle SMA f	-0.56dB SWR 1.22

A New (?) SMA to microstrip Transition

© Charlie Suckling, G3WDG

A new method of connecting the ground plane of a microstrip to an SMA connector has been developed as part of the effort to design some 2.3GHz power amplifiers.

Normally the body of the SMA connector is soldered to the ground plane of the microstrip directly, as shown in Fig 1(a). This method is used in the majority of microwave pcb designs. However this method causes some problems in power amplifiers when the pcb is to be mounted either flat on a heatsink, or just above a heatsink, in that the solder fillet on the ground plane side gets in the way, and the heatsink needs to be filed to accommodate it. Also, the connector has to be soldered to the board before the board is fitted to the heatsink, which causes major mechanical difficulties if the connector is not soldered perfectly square to the board, or if the heatsink is not exactly the same length as the pcb.

To get round these difficulties, a new method of grounding the body of the connector has been developed, where grounded pads of metal are provided on the top side of the pcb, and these are soldered to the connector with no connection on the ground plane side. In the prototype, three vero pins were used to ground each pad. The configuration is shown in Fig 1(b).

The performance of the new transition is shown. The performance of the conventional method is also given for comparison. In both cases, the microstrip was a 20mm long piece of 50 ohm line etched on 0.79mm thick material.

The launch to the other end of the line was via a conventionally mounted SMA connector. It can be seen that the new transition has almost the same performance as the conventional type, having better than 30dB return loss up to about 2.8GHz and better than 20db return loss to nearly 7GHz.

This type of transition is being incorporated into the latest prototypes of my 1W and 10W 2.3GHz power amplifiers.

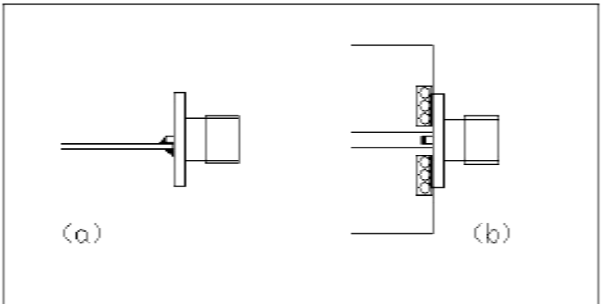
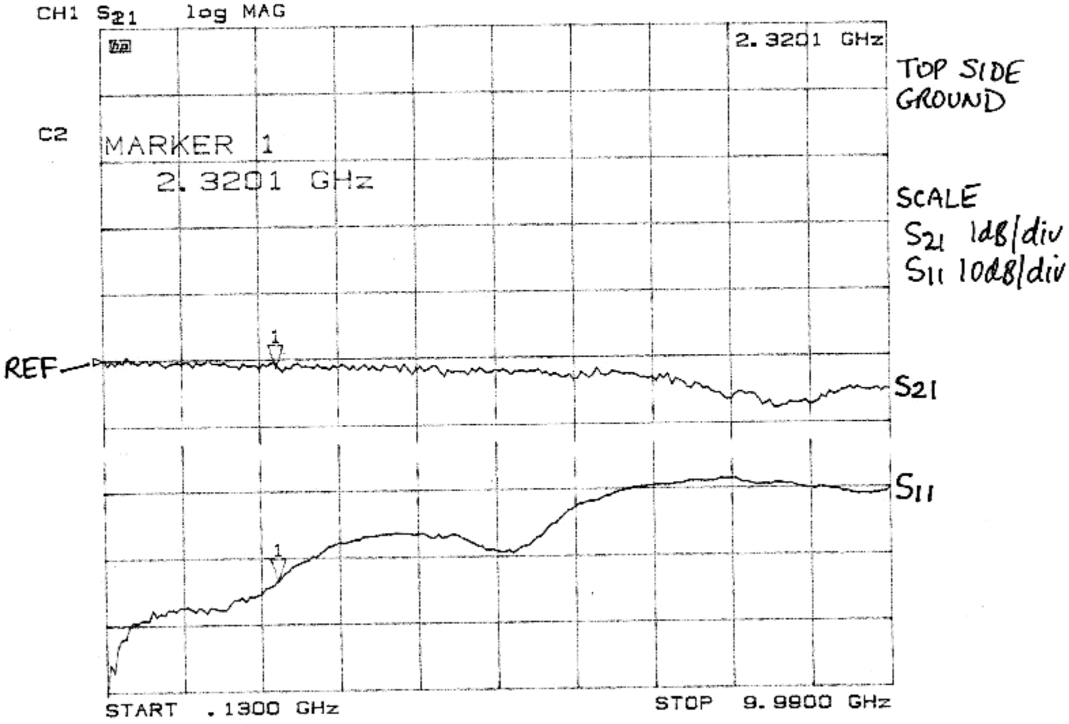


Figure 1



CH1 S21 log MAG
2.3201 GHz
C2
MARKER 1
2.3201 GHz
REF
START .1300 GHz
STOP 9.9800 GHz
TOP SIDE
GROUND
SCALE
S21 1dB/div
S11 10dB/div
S21
S11

Tips for Operating a Multiband Station

Uffe Lindhardt, PA5DD

Introduction

Being QRV on microwaves can involve being QRV at 5,6 or 7 different bands. Contests and band openings often requires fast QSY between these bands, as well as simultaneous operation on more than one band at a time (e.g. talkback). To fulfil these requirements puts high demands on the station design. This article tries to give some hints as to how this can be done.

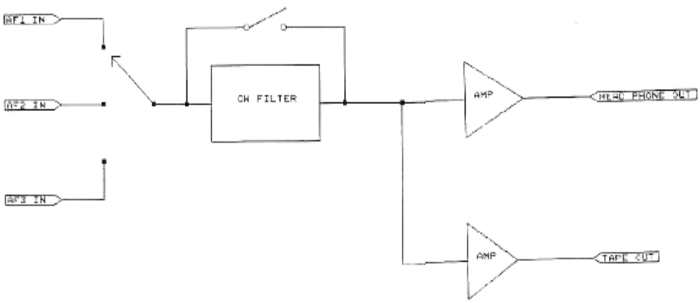
Audio and CW keying

In order to be simultaneously QRV on different bands, more than one transceiver is needed. As the choice of talkback varies (144 MHz, 432 MHz, 1296 MHz etc.) even more transceivers could be needed.

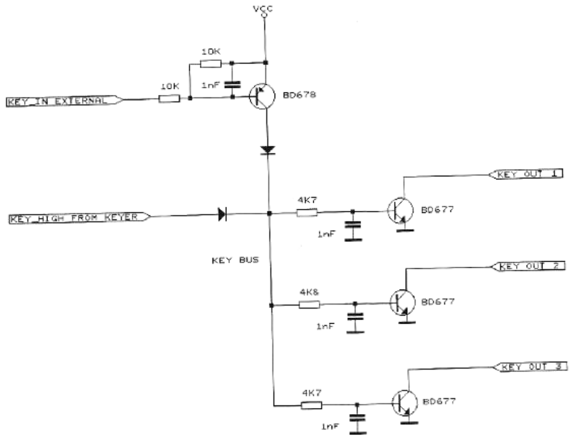
This naturally gives some switching problems when it comes to one headphone and one CW keyer.

For the audio part I have made a “Headphone amplifier box” which takes the standard 200mV AF output available on most commercial transceivers as input. For the sake of standardisation I have equipped all my transceivers (6 in all covering 1.8 MHz trough 24 GHz) with phono plugs for the AF output. Inside the box I have a switch to select one on the AF inputs. The input is then amplified before being fed to the headphone. Result: I do not have to plug my headphones in and out all the time. Taking advantage of the concentration of audio signals in the amplifier box, I have fitted a switchable audio CW filter and an isolated tape recorder / sound card output in the AF line going into the amplifier.

For CW keying I have chosen to key all transceivers in parallel. I am assuming, that only one transceiver will be transmitting at a time, so do not use break-in, or all your transceivers will be transmitting simultaneously. On the other hand this system removes any switching requirement for the CW key. In order to achieve keying in parallel and having isolation between the keying inputs of the transceivers, I have chosen to make a keying serial "bus", which is active high. This bus keys a series of NPN switching transistors, one for each transceiver. The bus is driven from my electronic keyer, which has an active high (inverse) output. Extra inputs to the bus for a hand key or PC interface can be added by means of an inverting circuit (e.g. PNP transistor).



This is the circuit diagram:



IF Switching
In order to bring down the transceiver count, it is natural to use the same transceiver for more microwave bands I prefer to use separate RX & TX cables for the IF connection to my microwave transverters. This "dual line" approach makes it easier to introduce separate attenuation in the RX or in the TX branch, when there is a need to adjust the signal levels. It also gives more transparency during fault detection on a mast mounted transverter. Furthermore I use split RX & TX cables also on the lower bands, so my transceivers already have separate RX & TX connectors.

I order to speed up the process of QSYing from one band to another, I have built some IF switches. Since separate switches are need in each branch (RX & TX), and maybe a third switch for the TX control signal, I have chosen low cost DC relays. These relays do not provide too much isolation on 144/432 MHz, but that is of less importance. I am using small "sugar cube" relays, which have a metal cover, that can be used for grounding. These relays can be found surplus at reasonable prices, and by using more relays a split of 2,4 or more IF outputs can be provided. If you are using a pre-amp and a PA on the fundamental band of the transceiver, then even that band could be connected to one of the IF outputs.

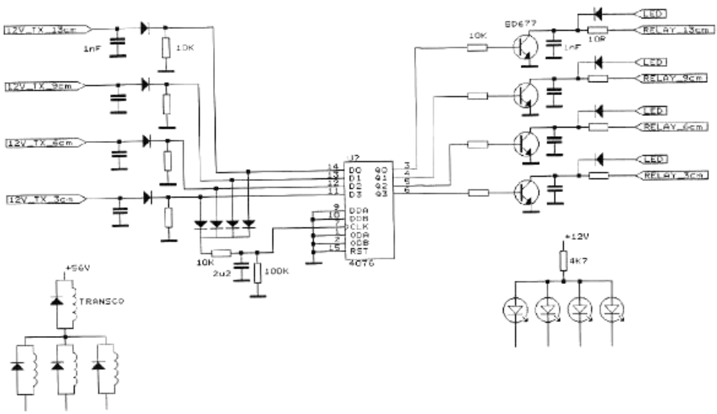
The relays could be internal or external to the transceiver, but it is an advantage, if the switching can be controlled from the transceiver. In my ICOM 402 I use the S-meter light switch voltage to switch the relays as well, this gives a good visual indication of which band I am on (e.g. lights off is 6cm, and lights on is 3cm).

Multiband Antennas
In order to make an efficient use of antenna mast space, it becomes desirable to make use of multiband antennas, e.g. a parabolic dish with a multi band feed. If at the same time the transverters have been placed in the mast to minimize cable losses, a need for switching between the antenna and the transverters occurs. Fortunately multi pole microwave relays are available e.g. TRANSCO

14300, which is a SP4T relay.
In order to make the switching as seamless to the operator as possible, I decided to make some control logic, that switches the relay to a given band when the transverter of that band is switched to TX.

Afterwards the relay stays in that position until another transverter is switched to TX. With this system the operator simply has to flick the PTT on a given band to acquire a connection to the multi band antenna.

The control logic was realised with D-flip/flops, connecting the TX/RX switching signals (e.g. 12V_TX) output signals of the transceivers to the inputs, and using the RX-to-TX transition of any of the signals to clock the flip/flops. The schematic below shows a system for four bands using the TRANSCO relay.



A Tracking Modulator/Detector System for Measuring Microwave Cavities

John A. Share, G3OKA

A simple method of determining the resonant frequency of a newly made cavity is to excite it with a low level signal from a generator and to look for a peak in the detector output. A typical microwave signal generator will deliver +10dbm and when lightly coupled to the test cavity the resultant signal from the detector is probably less than 1 mV. Amplifying this direct current signal can pose numerous problems, an established solution is to amplitude modulate the signal generator and measure the amplitude of the modulation from the detector. This is an ac signal and being at audio frequency its amplification poses few problems. A fundamental problem does exist in that the detector output contains not only the required audio frequency but also noise and 50Hz. Some filtering is therefore essential.

The ready availability of integrated Active Filter devices, and the ease with which they can be configured for centre frequency and selectivity make them an obvious choice. Their centre frequency is controlled by their clocking rate, the devices used had an on chip oscillator that required only two external components, or they could be clocked from an external source. This clock was also used to generate the modulation, if it varied then the detector filter tracked the modulation. High selectivity in the detector filter could then be used to improve the signal to noise ratio. A number of MF8CCN and 741 Operational Amplifiers were immediately available and a circuit was designed using these devices (**figure1**). There are other, probably better, devices that could be used. All the circuitry is at audio frequency and there are few constraints on the amplifier devices, circuit layout or construction.

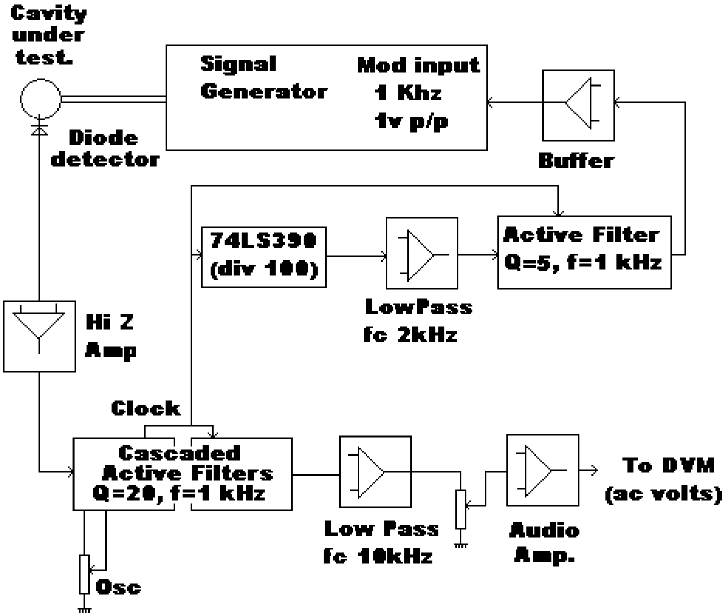
The cascaded detector Active Filters have a hardwired Q of 20, this was found to be more than adequate, and the centre frequency was selected for a nominal 1 kHz, clock rate is at one hundred times the centre frequency. This clock is also divided in a dual decade divider (73LS390) generating a 1 kHz square wave. A simple low pass filter with a cut off of 2kHz removes the odd order harmonics from the divider output and passes a recognisable sine wave into the modulation Active Filter.

This is hardwired for a relatively low Q and its output is a sine wave of good purity. The modulation frequency and the detector filter centre frequency are thus locked.

The MF8CCN has a relatively low input impedance, as such it excessively loaded the detector and a high input impedance amplifier was laced between the detector and the filter. The design constraints on this stage are negligible, it needs to have an input impedance of >1 Megohm and a bandwidth of a few kHz and was built around three 741 Op amps with a nominal gain of ten.

The Low Pass filter following the Detector Filter is necessary to remove switching transients at clock frequency that are superimposed on the output signal. It is possible that a passive R/C filter would remove these spikes but an active stage eliminates them completely. The Audio Amplifier simply increases the amplitude to a convenient level for the Digital Volt Meter. The Keithley 199 DMM that was used as the output indicator is able to measure ac signals at Audio and there was no need to rectify the signal.

This circuitry has been used extensively in the measurement of cylindrical cavities developed for use at 9 GHz and 14 GHz.



Tweaking Commercial Ceramic Filters

Kent Britain WA5VJB

WB0TEM picked up a large number of these 2332 MHz Ceramic Filters. He then pulled a dirty trick by giving me 50 of them!

They will work, as-is, at 2304MHz, but the response is falling fast and then you need to try a few to find a good one.

Marc was hoping I could figure out a way to re-tweak them. It seems that you can!

Find some solid copper wire that just fits back down the centre opening

of the ceramic element, something in the #20-#24 range. The same size wire might not fit all the elements.

Now tweak away. If you go all the way in, the element will short out, but there is a space near the bottom where you're retuning the filter element. I got these to go down to 2275 MHz, a drop of over 50MHz with little trouble. Next, a dab of RTV (or my favourite, Liquid Nails) to hold the

wires in place. Then trim off the excess wire after the glue dries.
Super Glue wicked all though the filter making a mess .... I don't recommend Super Glues!

Static Sensitive Devices and Fingers
Static Discharge Experiences

Julian G3TFR

I am all too painfully aware of the effects of major static discharge, which can be encountered in some homes, or in office areas, even of electronics factories. One office carpet I knew would, on a dry day, raise a body to some tens of kV after only a few steps across it, resulting in a powerful jolt and involuntary, minor, muscle spasm, on touching the first filing cabinet or earthed metalwork. I tried a couple of measures to protect myself from this, carrying either a 10Mohm resistor to damp the oscillatory discharge, or a coin or key to spread it over a greater skin area to reduce the current density. A good 'crack' would then be obtained, with little finger-pain, though the arm muscles would still spasm.

It intrigued me that some people appeared quite insensible to such discharges - I would notice from the corner of the eye that someone was approaching and about to lean against my filing cabinet, and while I was still trying to formulate a verbal warning, they would put out a hand to touch the cabinet, just as they began to speak: "I say, could you (KRRACK!!!) find me - er, what was that funny noise? - er, find me that purchase specification..." They literally hadn't felt a thing, just heard it, whereas I would have twitched and jumped, and would kick the filing cabinet for its audacity. So, I was more keenly aware than some, of the unstoppable discharge current of such a charge, and obviously no semiconductor device could survive such a discharge. The charge could easily be carried from the office to the bench. Merely pulling off an acrylic pullover while at the bench could prejudice everything in sight. Latterly, my procedure for protection from pullover-static is to touch, with the palms of the hands, a wall, preferably plastered brickwork, even if vinyl-emulsioned, which will safely discharge one in a second, without sensation.

PROBLEMS IN THE KITCHEN

'Laminate' wood-effect flooring also causes static charge accumulation, and a friend has frequent trouble from this in her kitchen. I noticed her FM radio on the worktop seemed to have become very insensitive, so I undertook to check the first RF transistor. I thought "if only they had bothered to isolate the device from the telescopic rod with a small-value series capacitor, or a small-value shunt RFC" and was then surprised to find both were fitted, but could not protect the bipolar device from the dreaded static.

ANTI-STATIC PRACTICE IN INDUSTRY

Most (all?) industrial electronics assembly facilities nowadays enforce strict static protection measures, including: anti-static clothing, tools, packaging, storage, stationery, conductive flooring and conductive over-shoes, the flooring often consisting of a vinyl surface, but with flecks of black conductive elastomer connecting through to a conductive/resistive backing earth leads for personnel, connecting either to wrist straps or to studs on the conductive clothing which in turn have conductive elastic sleeves static-dissipative (capacitive) or conductive worktops, connected to ground

Note that all conductive paths such as ground straps, worktops and floors, are protected by high-value resistors or by highly resistive materials. A strict regime of tests and safety checks is employed and documented, including daily checks on all wrist straps. No operatives are allowed to work on the benches without these measures, and entry to some factory zones may be restricted.

MISATTRIBUTION

I am always contemptuous of attempts to make engineers wear wrist straps under all circumstances when working at the bench. They of all people should be aware of whether or not that is necessary, just as the competent driver should be aware whether or not it is always necessary to use the indicators. I would say that even rudimentary measures will eliminate the risk of static damage, and though I have often seen device failures at work which are attributed to 'static damage' I believe that such attributions are usually superstitious. Closer inspection will almost invariably reveal a 'true' cause. Microwave power FETs may destructively 'hoot' while being shimmed, sensitive Schottky diodes may be blown by induced earth-loop currents, internal bonds in MMICs may fail during soldering, or even spontaneously if manufacturing standards are poor.

A WARNING

I was recently asked to work on some microwave Doppler units (long-established microwavers will recall these things with affection - see G3PHO's webpage article, "A History of 10GHz"). They consist principally of a bit of waveguide containing a Gunn diode which will always measure dead short on a DVM, but isn't, and one or two mixer diodes, which are seriously delicate, with reverse breakdown ratings around two to three volts - you can destroy them with the wrong DVM. I was seeing a large percentage of dead diodes, but found one good one and measured its sensitivity and ten minutes later, to my considerable chagrin, found it to be dead. I had even been using the blasted wrist strap, to please the client. Now, preparatory to starting this work, I had spent a day or more rebuilding the pair of fine old lab PSUs I intended to use, paying particular attention to replacing the mains leads, and observing 'best practice' by connecting the earth conductor using a crimp terminal, with star washer and lock-nut. They had MK plug-tops, which are the only ones which do not work loose their connections. Checking after the disaster, my DVM showed-up 100V AC between the two PSU outputs, though the static sensitive fingers had not felt anything. This turned out to be due to slack screw terminals in the mains socket boards under the bench. Microwave constructors, go and ponder your own vulnerabilities!

MY RECOMMENDATIONS

1) Run a safety earth wire between every individual piece of equipment used on the relevant bench, connected to earth terminals where provided on the equipment, or to any convenient case screw.
2) When making periodic checks on earth connections, do not use a DVM as the response time is too slow to catch short intermittent breaks. Use a fast-responding buzzer, or a lamp-bulb and battery and waggle the cables.
3) Assume that the earth continuity of all mains sockets is suspect until checked and, once checked, assume it will fail sometime in the future.
4) Appreciate that copper wire will slowly deform under high pressure, which is why the cable connections on sockets, and non-MK plugs, nearly always loosen with time.

Soldering 'pipe cap' filters on a DEM 10GHz Transverter board

Bob, WA5YWC

I recently purchased the DEM (DownEast Microwave) 10GHz transverter through the North Texas Microwave Society project.

During the assembly of the transverter, I came to the part about soldering the pipe cap filters to the pcb with a propane torch. I was a little uncomfortable with this method without first experimenting with a sample pipe cap.

First, I cleaned a copper cap with Scotchbrite and decided to tin the open end with solder. The results, in my estimation, were unacceptable. The pipe cap didn't tin very well due to excessive heat from the torch and was all black and nasty. I was not about to destroy my transverter board with poor soldering and excessive heat from a torch!

I came up with a much friendlier solution: use a heat gun. I purchased a Paladin heat gun at the local electronics store. It comes with three different removable nozzles and variable heat range. I also have a cheap, metal soup ladle (found in any grocery store kitchen gadget isle) I use for ladling hot solder for making fishing sinkers. By unwinding about six or seven feet of solder from the roll and placing it in the ladle, I heat the solder with the heat gun. It melts very quickly.

Next, I heat a shiny pipe cap with the heat gun and dip the open end in solder paste. Quickly, I put the open end in the hot solder and apply more hot air from the heat gun. The solder tins the end of the pipe cap very uniformly, inside and out, to a height of approximately one-eighth inch. I clean the pipe cap with alcohol and it is still bright.

With this method, I prepared all nine pipe caps for the transverter. Now, it was time to solder them to the board.

I followed DEM's instructions to mount the board to the aluminium pallet. With the heat gun, I pre-heated the pallet and board assembly. Taking a prepared pipe cap, I heated it for a few second to get the solder flowing. Then, I dipped the cap into the solder paste and dropped it in the appropriate hole in the pallet. Now, applying heat in a circular motion, and applying a small amount of solder in the corners of the pallet holes, the pipe cap was uniformly soldered in place. I continued with this method until all pipe caps were in place.

After the assembly cooled, I removed the board from the pallet and found nine, perfectly soldered pipe caps.

I cleaned the assembly in alcohol and baked it in the sun for a few hours.

I hope this information will be helpful for those intimidated by using a propane torch on this great microwave project.

Bondage …

© Lehane Kellett, G8KMH

Yes, you are reading BackScatter and you haven't picked up the wrong book! I guess I should really have titled it Bonding but that may have been as bad.

So let's straighten things out! I'm talking here about wire bonding, the 21st Century soldering iron. I was prompted to write this as I prepared to start some commercial prototyping and also many will have seen DB6NT's 47GHz amplifier at Martlesham.

We are all now familiar with the use of SMD components and these, at least in commercial usage, get ever smaller. 0402 is a pretty common passive device size in many portable devices and SOT363 for actives. How do you get smaller? And why? One of the reasons is to get even more into one area and the second is that at even higher frequencies (>c.20GHz) lead lengths and package parasitics kill the device performance. So the only thing to do is to connect directly from the active device to the circuit lines/microstrip. And for this you need to bond to the die and the track. Sounds easy?! Hardly, typical microwave devices (MMICs) are 1.6mm x 0.8mm and individual FETs and capacitors even smaller. So as you can imagine the wire used is extremely fine – usually 25um (1mil) and made of exceptionally pure gold, although aluminium is used in other branches of microelectronics. As an aside, it is also exceptionally expensive – 20m of 1mil on a spool is $375. So we have the wire, lets solder it to the chip….

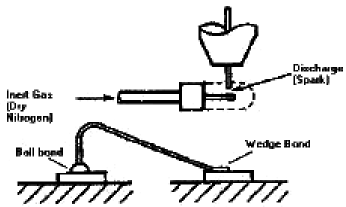
You first! My Acme soldering iron tip is a tad large. It just isn't feasible to use soldering techniques (OK, the smartass who said Indium solder gets a Gold Star) or even use conductive epoxy. The solution, which has been around for a very long time, is to weld the wire to the pads on the die and to the tracks. It really is welding too, the wire is pushed against the pad/track and enough energy applied to get the two to alloy and not enough that they melt completely – or destroy the die. Usually the materials are identical too which is why you see so much Gold inside commercial equipment.

So the trick is to have a machine that can spool the wire, hold it down and apply energy, then do it again and finally break the wire off. It may sound like a bit of a tall order but they exist in many shapes and sizes (and costs!) and are known as wire bonding machines, no surprise really. Well known names include Hughes/Westbond, Kulicke & Soffa and Hybond (the picture is a Hybond 572A at Queens University, Belfast)

The trickiest bits are getting the force right and applying the energy. The first is solved with some simple mechanics and in modern machines, strain gauges. And with the second there are two main methods of bonding – thermosonic/ball bonding and thermocompression bonding.

Ball bonding relies upon creating a blob of molten metal just a fraction of a second before the wire makes contact with the preheated die/track/ package frame and then it is pressed down. Why pre-heated? If you think about it, putting a hot blob against a cold piece of metal isn't going to give an alloyed joint. This method of bonding is ideal for some devices and probably a large proportion of silicon transistors and IC's use this technique. The magic TLA here is EFO – Electronic Flame Off. The reader is left to other interpretations.

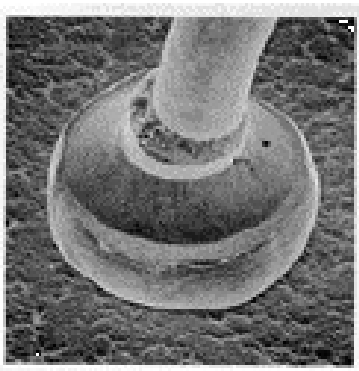
After the first bond is made to the die then the wire is pulled through the

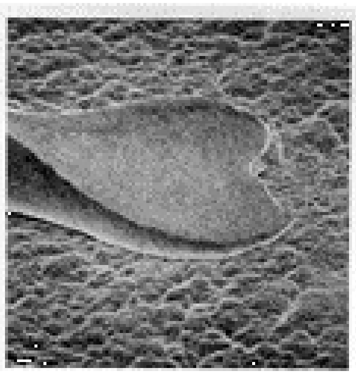


bonding tool and then pressed onto the track/frame and ultrasonic energy used to make the weld.

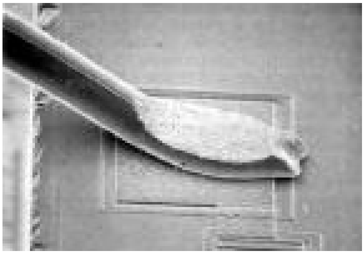
Ball bonding isn't used much with microwave devices. Thermocompression bonding is the workhorse of microwave electronics and is used for everything from mounting MMICs to linking modules. In this case the tool used is more wedge shaped and the wire (or ribbon) is fed through the tool at an angle—45° or 30° are standard. The wire is then compressed against the pad and a burst of ultrasonic energy used to create the bond. The tool then lifts and wire is fed through the tool until the second bond position is reached and the process is repeated. This may be the final bond or there may be another – this is used when the connection from the MMIC first goes to a decoupling capacitor (Di-Cap) before going to a supply track. The wire is simply broken by clamping the wire as the tool is moved upwards, it then breaks at the weakest point. Heat is provided to the die/ assembly on unit known as a work stage. Typically this is heated to 125C. Some processes call for the tool to be also heated in place of, or in combination with, the ultrasonic burst. Every MMIC manufacturer seems to have slightly different bonding parameters. As you may imagine, all of this requires everything to be scrupulously clean, as any residues or particles will cause bond failure. Much commercial processing takes place inside clean rooms but it is possible to maintain sufficient cleanliness inside a filtered air cupboard, usually know as a Laminar Flow Cupboard – many universities do this.

And in order to keep everything clean, the wire, devices, etc. are kept in a Dry Nitrogen atmosphere.





So, you fancy having a go? Well you can certainly pick up good used bonding machines from £800 up but you'll need to add the Nitrogen storage facilities, bonding tools, gold wire and clean room facilities. Say £3-5000 to start.



Makes that soldering iron look like a bargain, doesn't it!

Running Beacons from an Unstable 12 Volt Supply

Andy Talbot, G4JNH

From the outset we aimed to run the GB3SC# family of beacons from a 12 Volt battery backed up supply in order to simplify individual units and make them less susceptible to short mains outages (like using a kettle on site which drops the mains voltage to 120V!). The 2.3 to 5.7GHz beacons were made up as normal, designed to accept the straight 12V input from the battery which was often used directly for DDK004 type multipliers and crystal heaters - we never thought about the implications of interactions between equipments.

The first version of GB3SCX had been built using a mains power supply giving 14V and had proved adequately stable. When converting to 12V operation at its rebuild stage to uprate the PA last year, I noticed that the RF line up was quite susceptible to frequency shifts with supply voltage.

So, from the outset, I had to ensure it was properly regulated and able to cope with whatever a battery supply could throw at it. The DDK004 RF multiplier needed at least 11V to give enough RF output so, assuming a battery voltage that could shift over the range 11 to 15V, it was obvious that simple linear regulators were out. The head unit with its 2.5 to 10GHz multiplier and PA, included its own regulation, so could be left to fend for itself using raw battery supply. So now it was only necessary to supply the DDK004 source. The Farnell / RS catalogues list a plethora of small low cost encapsulated DC / DC converter modules rated from 1 Watt upward. The cost of these increase considerably with power rating so the lower rating we can get away with, the better.

Since a target voltage of 13.8V seemed to be about right, and I wanted to include a linear regulator anyway, a raw converted output of at least 15V is called for. To minimise the rating needed for the DC/DC unit, the isolated output from this can be added to the source voltage, rather than supplying all of it, so the DC/DC module only has to supply a portion of the power needed for the final unit. I already had a 1 Watt rated 12V to 12V converter (NME1212S, Farnell Part No. 178-197, the cheapest they do) from an earlier project and used this in a circuit similar to Figure 1. It could only give 80mA output which rather marginal, but just about sufficient for the DDK004 alone. An LM317* was used as a linear regulator to allow 14V output (7812 regulators jacked up with a couple of diodes are disgusting and should be banned by law!).

With DC/DC converters, EMC is always an issue and I fully expected to have to include plenty of decoupling to remove spikes and noise at the switching frequency. Filtering was built in from the start and proved to be necessary.

Even with the one input and two output stages of filtering as shown, sidebands at -60dB are detectable on the RF output at a few hundred kHz away. All worked as expected and this PSU is the version in current use on GB3SCX. It works properly over the input voltage range 10.5 to 15 Volts (although with slightly reduced power output at the lowest input voltage, down to the design of the 2W PA stage)

As a number of listeners know and complain about, GB3SCC, the 5.76GHz beacon, operates on a time cycle which was initially 40 seconds on and

40 seconds off (now 40 and 20 seconds respectively for a trial period). I noticed that the frequency of GB3SCF on 3.4GHz changed audibly—in fact by about 30 - 40Hz when GB3SCC switched on and off. As this uses raw 12V for some of its stages, the frequency shift is to be expected. What I hadn't bargained for was a slight (about 10Hz) residual shift on GB3SCX in spite of the, now, highly stable supply. Also it wasn't a sharp shift such as that observed on 'SCF. Instead the frequency would change slowly over a few seconds and even appeared to overshoot slightly at times. It looked as if the crystal heater was to blame, changing the frequency as it warmed and cooled with the approximately 150mV supply voltage variation. I haven't measured this effect any more accurately, and the next version of the beacon will use a phase locked approach, not calling for a crystal heater.

I will also need to adopt an uprated DC/DC converter to supply the PLL unit as well as the multiplier. It is not necessary to generate 12V in order to add to a worst case battery input to get 14V, and a lower output is desirable as it allows greater output current for a given rating. In the NML 2 Watt range, output voltages of 5V and 9V are listed. 5V will do for most applications when added to a battery supply of 12V but with a worst case of 10V input (especially if an 'idiot diode' is included in circuit) is too marginal for a guaranteed 14V regulated output. So the 9V NML1209S (Farnell part No. 305-8311) will be used for the next version allowing 220mA of current capability. GB3SCK, on 24GHz, was initially built as a mains powered unit but, after pressure was applied to him, Chris G8BKE converted to 12 Volt operation. To do this he had to incorporate an inverter to supply the 20 Volts needed for its 'brick' PLL oscillator. The first version used a low power packaged DC/DC converter for this task alone, with all the other modules using 'raw' 12V and sometimes regulating this down. Occasionally 24GHz would go completely unstable with the frequency shifting wildly and this was put down to the 5.7GHz unit changing the supply. This time, Chris just took the quick approach just went for a big DC/DC converter that was to hand, generating 20V and regulated down to 12V.

Now the whole beacon complex operates off a battery supply, although the two lowest frequency beacons still have slight frequency shifts as GB3SCC cycles - these may be updated eventually as part of the project to make them all phase locked.

Note for users of LM317 Regulators ...

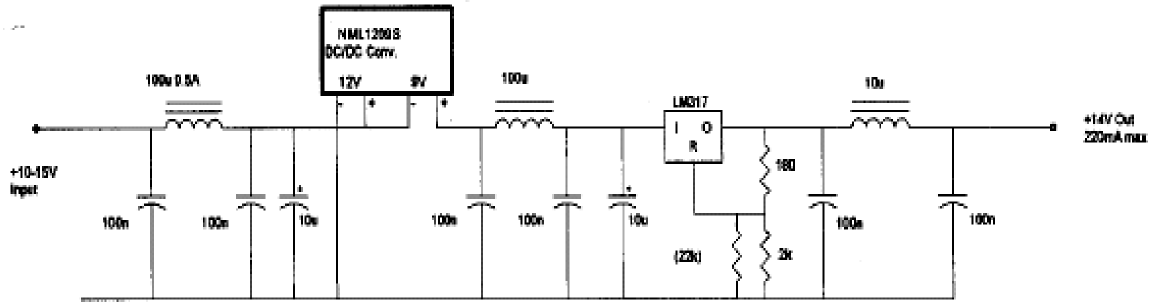
There is an occasional tendency when using the LM317 for users to add decoupling capacitors to the adjust, or feedback, connection as well as between both input and output to ground. Perhaps they feel that as there is no capacitor directly across device pins, the decoupling won't work properly.

This is wrong, even though the device will appear to regulate voltage correctly.

The voltage adjust pin has to carry the high speed feedback signal corresponding to output load changes. Any capacitor added here destroys high speed transient response of the regulation and allows hum and noise to go straight through.

I once saw this error on an LM217 used in the voltage regulation circuitry of a piece of hardware destined to go on a communications satellite. The mistake had gone right through initial bread boarding, and was only detected when the unit dismally failed its EMC tests for conducted susceptibility on the evaluation model.

Figure 1: circuit diagram of the 220mA rated 14V supply to be used for the next generation phase locked GB3SCX source.



Sulphation of Lead Acid Batteries

Steve Davies, G4KNZ

I was wondering if anyone had come across this method (below) for removing lead sulphate crystals? Has anyone actually tried it, or got one of the "conditioners" from VDC? Or does it not really work?

Read on ….

When a battery is improperly charged (over/ under) or allowed to self-discharge, as occurs during storage/ non-use, crystals of lead sulphate (PbS04) build up on the battery's storage plates, preventing the battery from ever being fully charged and therefore able to deliver their full power/ capacity.

Every element has a magnetic moment at a resonant frequency i.e. a point at which the chemical bonds that hold the molecules together to form a crystal can be broken. The resonant frequency of lead sulphate crystals is 3.26MHz.

By creating a waveform with the required 3.26MHz frequency, coupled with a very fast rise time and a high amplitude pulse, the sulphation can be broken down.

This approach is used in a battery conditioner from VDC Electronics.

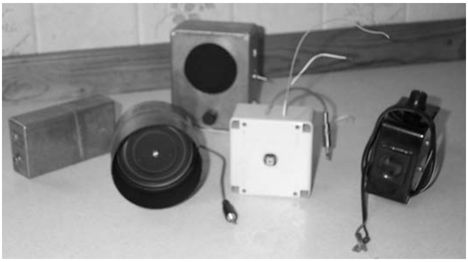
Note: Not every battery is a candidate for reconditioning - for example, failure may be due to mechanical damage caused by vibration or contamination, which has created is "shorted" cells. But If a 12 volt battery has a resting voltage of at least 10.5V and none of the 6 cells are shorted, desulphation of its plates can be accomplished.

High Performance, Low Cost Lightwave RX Front End

Gordon Fiander, G0EWN

The following describes a low cost-high performance lightwave RX that combines parts of the K3PGP design with G0MRF stages.

My first RX was based on G0MRF design but used OPT101 front end. These are still available, via Farnell for around £4.00. The OPT 301 is no longer available as far as I can gather, which is a pity as they have slightly better characteristics than the 101. In practice, however, performance of the 101 and 301 are very similar; a test over a 10km path with Barry, G8AGN TX, and Peter G3PHO (using the OPT301) and myself RX, G0EWN, (using the OPT 101) showed little, if any, difference in performance (both received G8AGN at 59+).



Following the above test earlier this year, I decided to experiment with a PIN diode front end. This was based on the K3PGP design. I found Maplin sold a 5mm package PIN photodiode, the Siemens SFH2030, costing only 79p. I used a 2N3819 in place of the MPF102 and omitted the second stage of the K3PGP design. The output from the 2N3819 was filtered and amplified by G0MRF's audio stages, which use low noise 5534 op amps. TL071/81's are very poor in comparison.

Output from David's unit then goes to an LM386 audio amp set at maximum gain. I compared the Pin diode front end with the OPT101 using a G8AGN weak signal source and found the PIN diode arrangement was much more sensitive than the OPT 101. Tests were made using exactly the same following stages and just substituting front ends. The PIN diode was capable of copying signals the OPT101 could not detect! These tests were made without any optics ahead of the two sensors.

I followed K3PGP's advice of using simple point-to-point wiring and shielding (see photos). By combining the first stage of the K3PGP design and G0MRF's audio filter/amp stages you get a high performance/low cost system that's very easy to construct and is an excellent starting point for dabbling in lightwaves.

G0EWN's lightwave receiver