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Radio Amateur Worldwide

Especially Covering VHF, UHF and Microwaves

VHF COMMUNICATIONS

Volume No. 23 . Autumn . 3/1991 . £3.50

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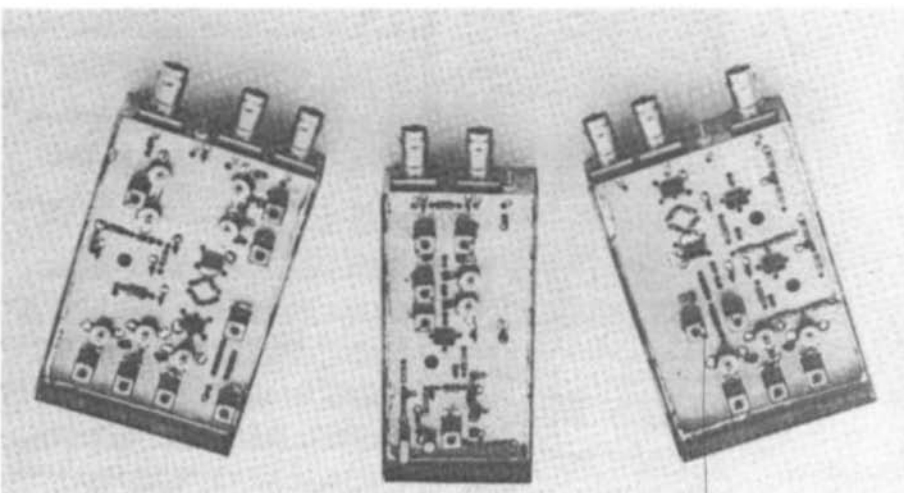

FOR 28, 50 & 144MHz

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Dr. Ing. Jochen Jirmann, DB1NV

A Digital Image-Store for the Spectrum Analyser

Equipped with an IF filter of minimum 1kHz bandwidth, the spectrum analyser DB1NV 006-009 can also handle narrow-band analysis of signals as well. Of course, to achieve this a very slow scanning rate must be selected (a few Hz) to avoid a static image on the screen. Some help would be given by a long-persistence tube but at the expense of image brightness. Much better is a technique used up to now in some commercial analysers of a combined non-storage and storage image, the latter with variable persistence. Unfortunately this kind of device is not commonly found on the used equipment market or when it is, it is in poor condition.

Therefore we now describe a purely digital image storage system which combines several interesting features with a relatively low-cost (under £100) material requirements, including:

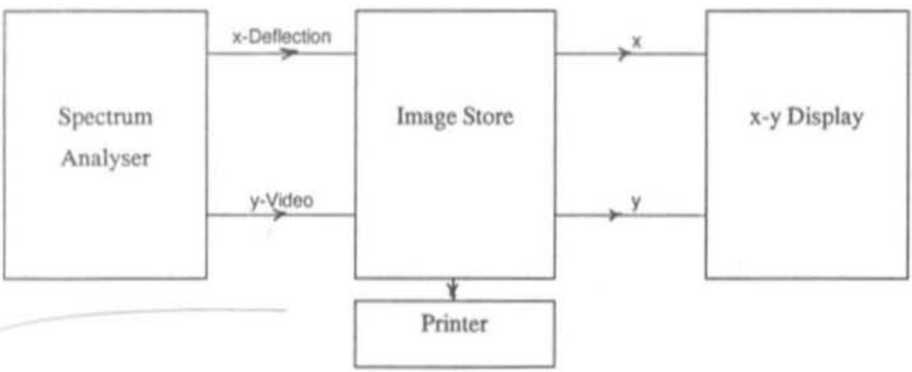


Fig.1: Image Store in loop-through mode

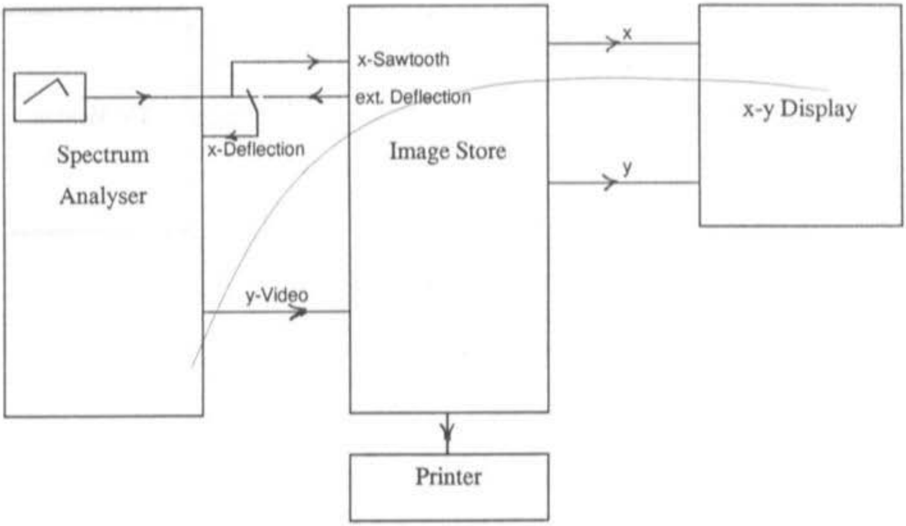


Fig.2: Image store with external control of Analyser

◆ the existing display can be re-used;

◆ thanks to CMOS technology, the power requirements are so small that the new construction can be added without the need for a supplementary power supply;

◆ since the spectrum data is already in digital form, graphic printer output is possible;

◆ variable persistence display is not provided, so no reference curve need be stored;

◆ simply-to-achieve digital averaging can, when required, improve the representation of noise-impaired signals.

The whole construction, with its digital circuitry, presents a powerful source of interference. Care was taken therefore to achieve good screening of the conductors and to build a compact, easily screenable unit no larger than a single Eurocard which would fit inside a standard screening case. Solutions involving an AT with high-res graphics were therefore excluded.

1. SOME IMPORTANT PRIMARY CONSIDERATIONS

To conceive an image store there are three solutions:

1. the loop-through circuit in Fig.1, where the image store is simply linked in with the lines for video (Y) and deflection sawtooth (X), allowing the choice of displaying either the original signal or the stored one. The advantage is that no modification is required to the equipment and that this image store is available for use with sweep generators, etc.

2. "remote control", as in Fig.2, with the precondition that the analyser has an external sweep port, since in image store operation the store will provide the deflection sawtooth. This normally means internal modifications to the analyser.

3. the "raster screen display" of Fig.3 demonstrates a complete change from the

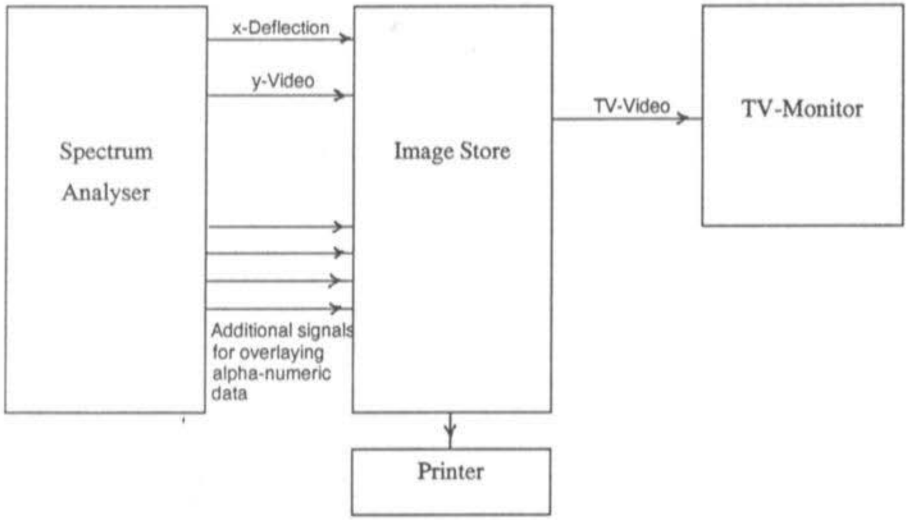


Fig.3: Image store with raster-display screen

previous techniques. A normal computer monitor provides the output here, the image store provides the sweep sawtooth, and the customary analogue display is dispensed with altogether. This demanding concept is employed in most modern industrial devices, allowing without further ado the overlaying of alpha-numeric information such as IF, filter bandwidth, etc.

The author plumped for the first variant since no internal modifications were required to the analyser, the existing display unit could be re-used and the image store might also be used for sweeping. (It is possible that a dislike of too much computerisation also came into it, since option 3 would probably have required a graphics computer with additional RF adapters.)

The basic circuitry of the image store is built up as a normal logic circuit with A/D and D/A converters as well as some counters and a store. The "Print Screendump" function on a normal graphics printer, however, can only be achieved in a sensible manner with the aid of a microprocessor. Therefore the complete circuitry of the image store is put on a single-chip microprocessor (80C31). If one uses A/D and D/A converters for direct connection to the processor bus, the circuit becomes extremely simple and the whole construction will fit inside a standard tinplate box with the measurements 72 x 144 x 30mm.

The next point is to clarify the resolution of the image. It is well known that (for example) weather satellite pictures with 256 x 256 pixels are easily recognisable. The present application makes higher demands, though. Whilst the Y axis can be digitised in 8 bits without difficulty (with 80mm picture height, that is around three dots per mm), the X axis needs finer resolution, as a simple calculation shows. With a display width of 50MHz/cm and a filter bandwidth of 200kHz, a theoretical total of 250 lines per cm or in all 2,500 lines can be drawn on the screen. This means digitising the X axis with at least 11 bits (2048 points) or better 12 bits (4096 points). A trial also with 8-bit resolution gave disappointing results.

To get a fairly stable on-screen display on the fairly short-persistence tubes used on most oscilloscope displays we need an image refresh frequency of around 15 to 20 Hz. Since the microprocessor used can deliver data out of the image store to the D/A converters at around 20kHz (assuming the processor spends half its time on image display), we need to accept a compromise on horizontal resolution, which is fixed at 10 bits = 1,024 pixels. Nevertheless A/D and D/A converters with 12-bit resolution are used, allowing users with longer-persistence displays (e.g. the GR screen used in many magnetic deflection displays) higher resolution at the cost of screen refresh frequency.

2. BLOCK DIAGRAM

The result is the block diagram shown in Fig.4. The video signal (Y signal) passes through a preamplifier, via a peak value hold stage, to the A/D converter with 8-bit resolution. The peak value stage ensures that between two readouts from the A/D converter no signals are lost. The Y signal coming from the store is fed to a D/A converter and after low-pass filtering via the output amplifier to the display. A CMOS analogue switch allows the source signal from the input to be patched through as an alternative. The same switching circuits, apart from the peak value detector,

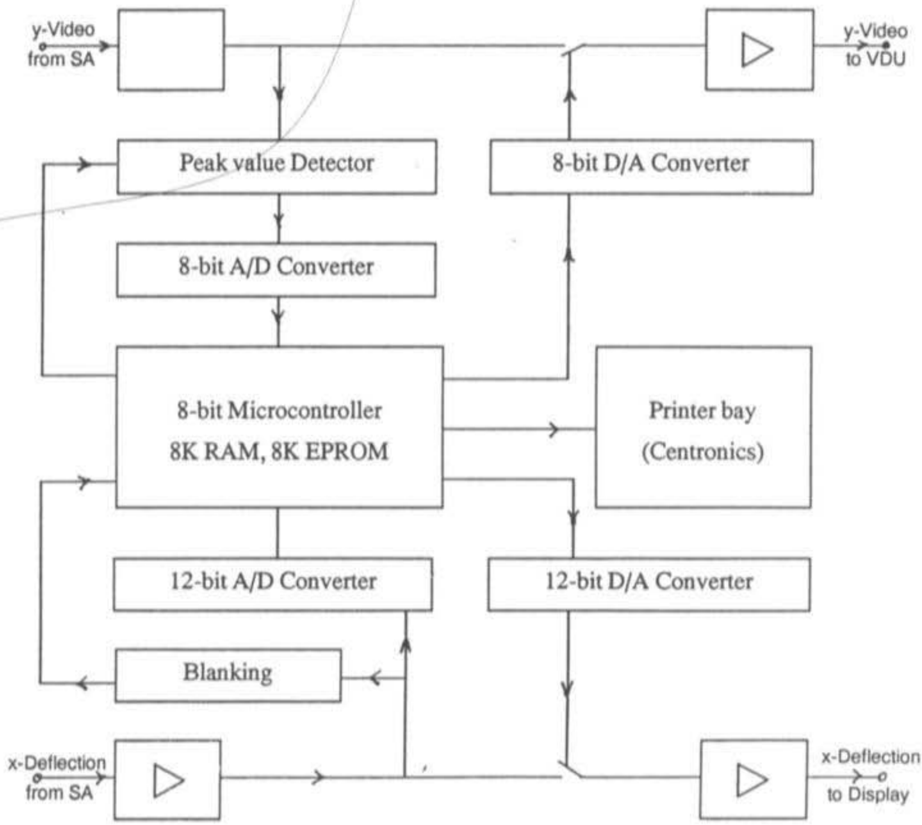


Fig.4: Block diagram of the Image Store

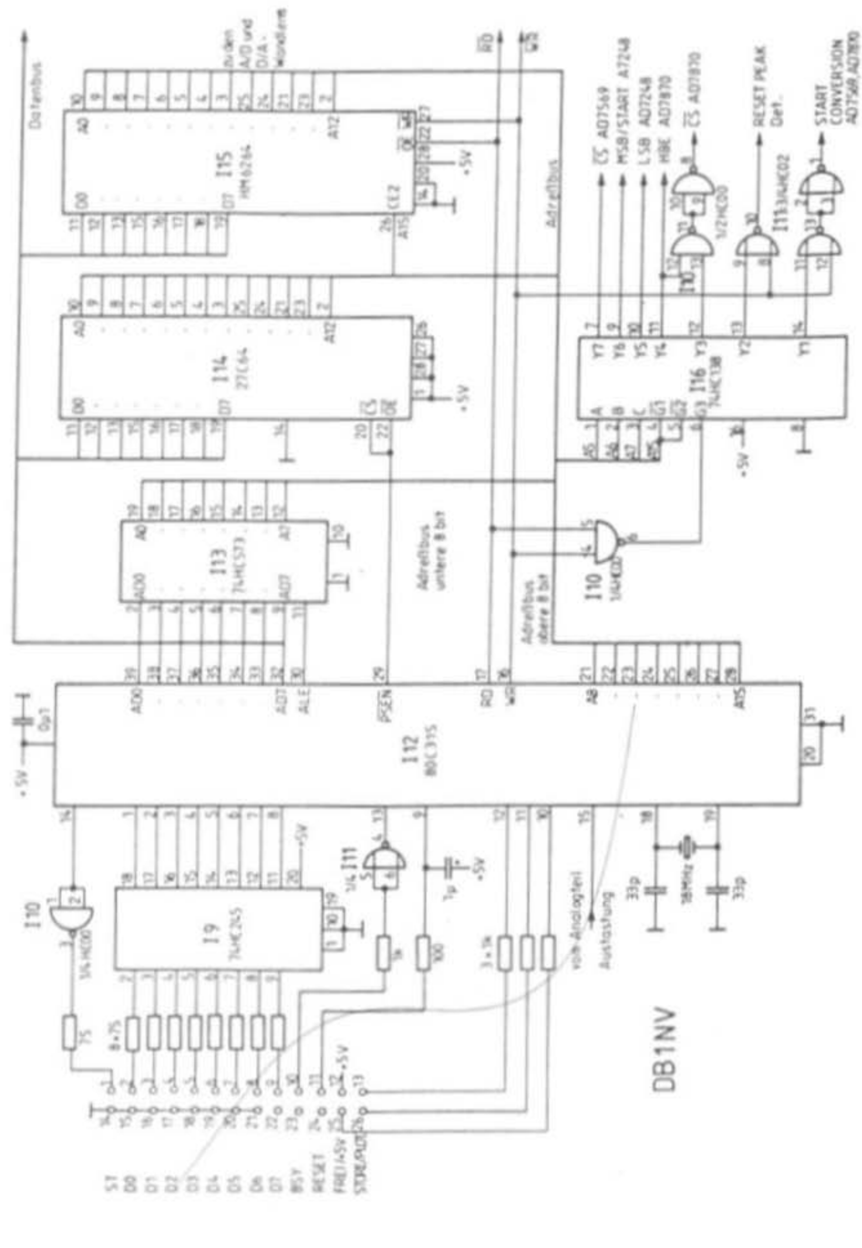


Fig.5: Digital Image Store for Spectrum Analyser - Part 1: Processor

are to be found again in the X channel, although 12-bit converters are used here. In addition the X channel has a blanking circuit to prevent measurement during the sawtooth's flyback period.

A microcontroller of the type 80C31 forms the centrepiece of the image store. Since not everyone has the capability of programming the EPROM version of the 80C31, the 87C51, the ROM-less type 80C31 is used and a standard EPROM is connected externally, even though this increases the circuitry. An 8 kilobyte CMOS static RAM is provided as external data store.

As well as reading and storage of the image, the microcontroller controls output to an external printer. Since printing out can take a few minutes during which the picture cannot be altered, measurement is interrupted during this phase of operations and the image is "frozen".

3. THE CIRCUIT IN DETAIL

As Fig.5 shows, the microcontroller I12 is connected to an external EPROM I14 (27C64-75) and a CMOS RAM I15 (HM6264). Since the address and data signals are addressed over a single port, the address latch I13 (74HC573) separates the two signal paths. This works as follows. Each time the external processor is addressed for the first time, pins 39 to 32 of the processor (with AD0 to AD7 = address bits 0 to 7) pass for one time period the low eight address bits. This state is indicated with logic high on pin 30 (address latch enable). The address latch I13 detects these address bits on its inputs (pins 2 to 9) and passes them on as static address signals A0 to A7 for further action via pins 19 to 12.

The high eight address bits come straight from the processor (pins 21 to 28) next to the static signals. After this operation the processor switches pins 39 to 32 as data pins D0 to D7, which are linked to the data in/outputs of the store and converter units.

In order to be able to address the store and converters separately, the following decoding scheme is adopted.

Upon seizure of the program store, pin 29 (program store enable, active low) of the processor activates, whereupon the EPROM loads its data via D0 to D7 to the data bus.

The CMOS RAM I15 is arranged into the upper 32K of the data address area. Activity follows with address bit A15 set, whereby the RAM is activated via pin 26 (chip enable 2). For reading pin 17 (read) of the processor is active low, whereas for writing pin 16 (write) is.

The A/D and D/A converters are connected to the lowest 256 bytes of the data address area. For this an address decoder 74HC138 (I16) is activated as soon as address bit A15 goes low and the bit sample on A5 to A7 determines which of the decoder outputs Y0 to Y7 switch to low and activate the appropriate peripheral unit. So that addressing activity with to the program store does not accidentally activate the A/D converter, the address decoder via I10 (pins 4, 5 and 6) is only made operational when either the read or write signal is active.

Mention must also be made that to minimise requirements, decoding of RAM and A/D converters is incomplete. It is thus "reflections" of the address regions that occur in the address area of the processor.

Since the microcontroller has to operate at 18MHz, a correspondingly fast version of the 80C31 must be selected, such as the type

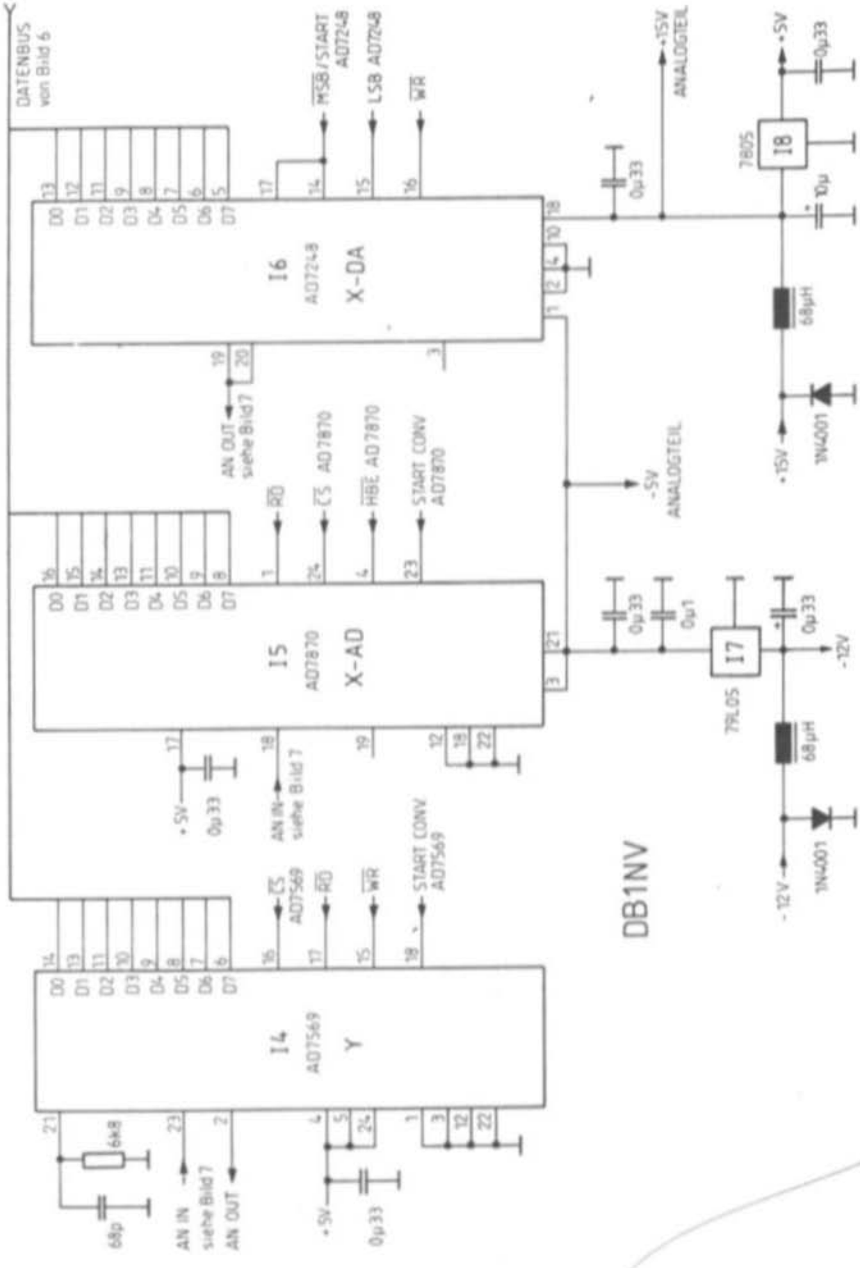


Fig.6: Digital image store for Spectrum Analyser - Part 2: A/D and D/A Converters

supplied as 80C31S by Matra-MHS or AMD. If only a standard 80C31 is to hand, then the crystal frequency must be brought down to 12MHz. The standard models often work at 18MHz but this cannot be guaranteed; the S types worked at up to 24MHz for the author but then the converters could not keep up.

The EPROM too must be a fast example, with an activity period of less than 100nS, such as the AM27C64-90 from AMD. The author even tried the 75nS version. Since this kind of exotica is not available in your corner computer shop, these must be obtained through a distributor.

Anyone interested in finding out more about the 80C31 microcontroller should investigate the handbooks by AMD (8-bit Microcontrollers) and Intel (Embedded Controllers, Vol. 1, 8-Bit). There is also an out-of-print book called "Die 8051 Mikrocontroller Familie" by Otmar Feger, published by Markt & Technik Verlag.

The computer kernel communicates with the outside world in three ways.

The A/D and D/A converters I4, I5 and I6 are directly connected to the data bus of the microcontroller. In order to address the modules separately, addresses are assigned to them on side 0 of the external data store (memory-mapped I/O). This is achieved by the address decoder I16, a 74HC138, which also produces the trigger signal for the peak value detector.

Some signals, like operating push buttons or sawtooth flyback, are led via port 3 to the controller.

Data for the printer comes from port 1, via a driver 74HC245 (I9), to the Centronics connector for the printer. The driver is only necessary for printers which conform to the Centronics norm and have low-resistance pull-up resistors of 470R or 1k to +5V. Modern printers often have high-impedance inputs and in these cases the driver is superfluous. The printer control signals (only Strobe and Busy are used in this application) also come from port 3 of the 80C31. For the printer any graphics-capable matrix printer with the Centronics interface and Epson control set. The author uses a Hewlett-Packard Thinkjet in "alternate" (Epson) mode.

To avoid multiple reflections on the line to the printer and related EMC problems, all output lines are terminate din 75R resistors. If this is insufficient, additional decoupling capacitors of around 470pF can be tried: they are best soldered direct to the grounding collar of the printer socket.

The author fed all digital signals to a terminal block and then through a plug and socket arrangement through a cable form to the printer socket and the press buttons (Reset, Start screendump, Store reference curve, Alternate display of reference and current spectrum).

The A/D converter section is shown in Fig.6. All three converter units are, with their data connections, connected direct to the bus of the 80C31. Additional bus drivers are not necessary on such a small set-up. The Y section (I4) is made out of an AD7569 from Analog Devices: this interesting CMOS IC contains an 8-bit A/D converter with presettable voltage range (selectable 0 to 2.5V or 0 to 1.25V). The AD7569 can also be run off a symmetrical +/-5V supply if negative input voltages are expected. Apart from an R-C element on pin 21, no other circuitry is necessary.

In the X section we have an AD7248 (12-bit D/A, I6) and an AD7870 (12-bit A/D, I5).

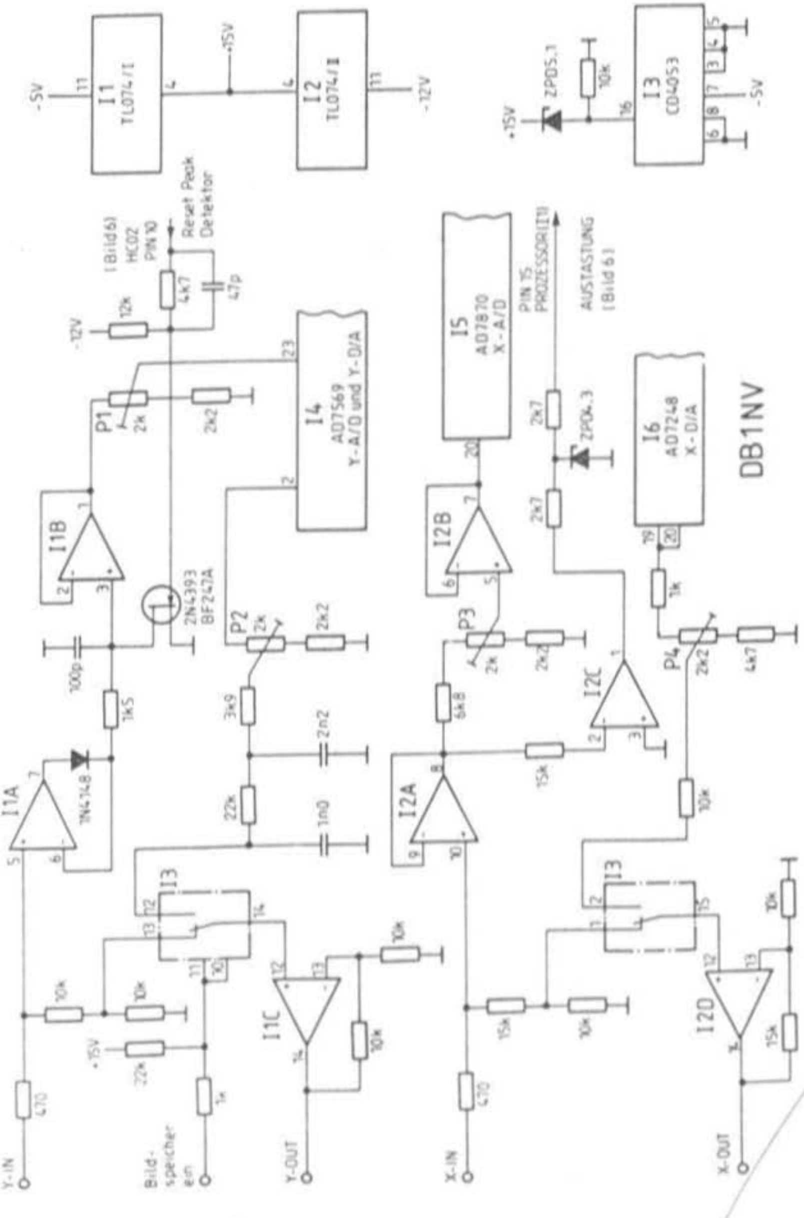


Fig.7: Digital image store for Spectrum Analyser - Part 3: Analogue circuits

Data transfer is made every time in two sections, with one 8-bit and one 4-bit word; the converters have control inputs to select the high and low-value data words. Both converters are provided with an auxiliary -5V supply so that bipolar input and output signals can be accommodated. Once more, apart from some decoupling capacitors, no external circuitry is necessary.

Fig.6 also shows the power supply arrangements for the image store. The +15V and -12V voltages taken from the analyser are fed via wrong-polarity protection diodes and L-C low-pass filters to the operational amplifiers in the analogue section. The AD7248 is also on the +15V rail. The voltages of +5V for the digital section and -5V for the A/D converters are produced with 7805 and 79L05 fixed voltage regulators.

The analogue signal handling is shown in Fig.7 and comprises two quad op-amps (TL074) and a CMOS analogue switch (CD4053). The Y signal with a nominal amplitude of 0 to 4V, corresponding to a dynamic range of 80dB from the logarithmic demodulator TDA1576, is led to the peak value hold circuitry made up of two op-amps (I1A, I1B) and a switching FET (2N4393 or BF247A). This is periodically reset by a processor command via the address decoder I16. This ensures that a signal peak is only assessed when the Y signal has passed the A/D converter twice.

A resistive divider, adjustable with P1, splits the signal from the 2.5V maximum coming from the AD7569. The output voltage of the AD7569 is split vice versa with P2 to around 2V before undergoing a simple low-pass filter and the CMOS switch in I1C ready for amplification by a factor of 2 for the display. The CMOS switch CD4053 can also patch the input signal with an amplification of 1 through to the display.

The X signal route is laid out for a voltage between +10V and -5V, otherwise similar to the Y channel. P3 serves here to set the signal level at the A/D converter AD7870 and P4 adjusts the output level of the D/A converter AD7248. Looping through of the X signal is done with the second channel of the CD4053. During flyback of the sawtooth the X sawtooth becomes negative (flyback blanking); this is recognised with a comparator (I2C) and supports via the port routing P3.5 (processor pin 15) the measurement process.

4. THE SOFTWARE

The author realises that most RF people treat microcomputer technology with some misgiving, for which reason this software description has been kept as short and intelligible as possible.

In the microcontroller of the image store there are normally two partial programs running quasi-simultaneously. One of these is the picture output. After enabling the image store, first the timer channel 0 of the 80C31 is activated and halted on a periodic interrupt mode. Every 50 seconds the 80C31 interrupts the program already running and carries out the following two functions. A 10-bit counter is switched in and the counter status fed out to the X D/A converter, which is producing on its output a sawtooth with 1,024 steps. Upon overflow the counter is reset to zero. The counter status also serves as an address for the image store, from which a Y value is fetched and fed via the Y D/A converter to the vertical channel of the display. The total running time of the program is around 25 microseconds, after which the 80C31 progresses the program execution to the interrupt stage.

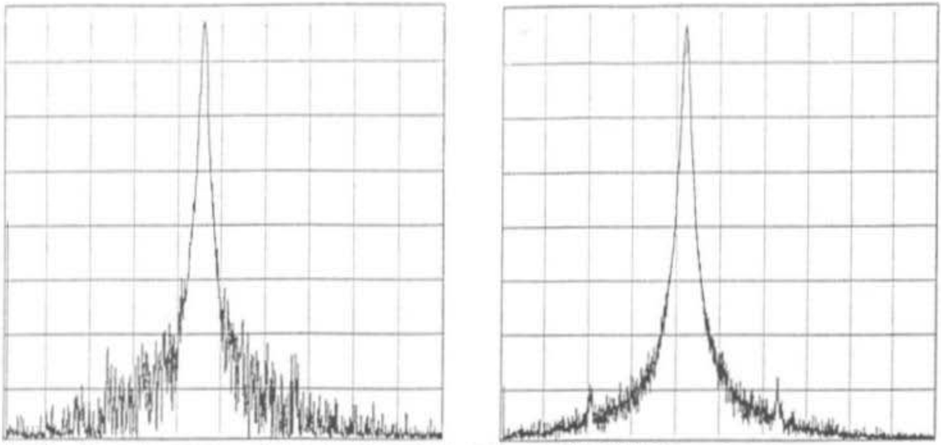


Fig.8: Sample screen print-out without (a) and with (b) digital averaging. The video bandwidth here is 100kHz.

In image store operation for the rest of the period the X and Y D/A converters are polled periodically and the peak value hold circuit is reset. The X value provides the write address for the image store, the Y value the data to be written there. During sawtooth flyback, detected by I2C, measurement recording is interrupted.

If screendump printing is activated by pressing the button, instead of the storage program, the plot algorithm is executed. To achieve this the amplitude values are turned into X-Y co-ordinates and passed line by line to the printer. The printer expects an 8-bit word per X position, which determines which of the 8 vertical pins (or plotting pens) is to be activated. For common paper widths 512 X positions are convenient. The complete picture is built up by 64 successive line-by-line operations of the 8 dots on each line.

Since the store of the processor kernel is not large enough to build up the complete graphic in the store, another technique is employed. The store is scanned 64 times and the plotting algorithm is used to determine which of the dots are to be printed. This apparently untidy solution does not cause any problems, since the microcontroller can handle this task without difficulty and spends most of its time waiting for the slow printer.

For improving print quality additional tricks such as double-pass printing can be indicated, but a full description would take up too much space here.

Before the plot data is finally fed out to the parallel interface, it undergoes a filtering program which adds a frame and grid scale.

In many measurement applications, a direct comparison between the actual measurement and a reference value is desirable, for example to check the effectiveness of alignment being carried out. This can be done by pressing a button to capture the current value in a reference store; after this the reference and the current spectrum can be displayed alternately. To avoid too much flicker on the image in reference mode, both spectra are drawn with only 512 pixels' horizontal resolution.

In order to find weak but stable signals in the noise an averaging can be called in. The smoothed averaging can suppress the noise that varies from image to image by around 6 to 10dB, so that correspondingly weaker signals can be observed (Fig.8a/b). The averaged spectrum can also be printed out.

5. ADVICE ON CONSTRUCTION AND OPERATING

The disentangling of a computer PCB with bus structures and fairly high packing density is only possible with some considerable effort and the use of multi-layer techniques. On account of the proximity of the analogue and digital circuits and its application in a receiver with interference suppression requirements, only a single plane PCB could be considered. Accordingly the author built the first prototype on a special experimenter's PCB which had a groundplane surface on top and 0.1" square copper "islands" for soldering below. As these boards are drilled only where there are components, they allow a significantly higher component density than normal experimenter PCBs. Wiring for the operating voltages is carried out with 0.5mm silvered copper wire, which gives the low impedance needed in particular for digital devices.

The remaining wiring is done with fine wire or better with wire-wrap wire (30AWG). The wire-wrap version is certainly more tedious (the insulation has to be removed) but in consequence is also more robust, since the Teflon insulation is soldering-iron proof.

If one follows the component layout in Fig.9, the image store can be put inside a tinplate case 74 x 144mm (Fig.10). The hard labour of wiring up the board (Fig.11) can be accomplished in one or two afternoons, and the packing density achieved avoids recourse to multi-layer technology. Sceptics may care to know that similar "drawn wiring" techniques using a computer-controlled wiring tool have been used even at NASA.

Whether the ICs need to be provided with sockets is for the constructor to decide; the microcontroller and EPROM should certainly use these, but please use the precision variety with turned pins. As ever, you are better off soldering than using cheap sockets: contact failures can occur in the primitive sockets, even with brand new stock.

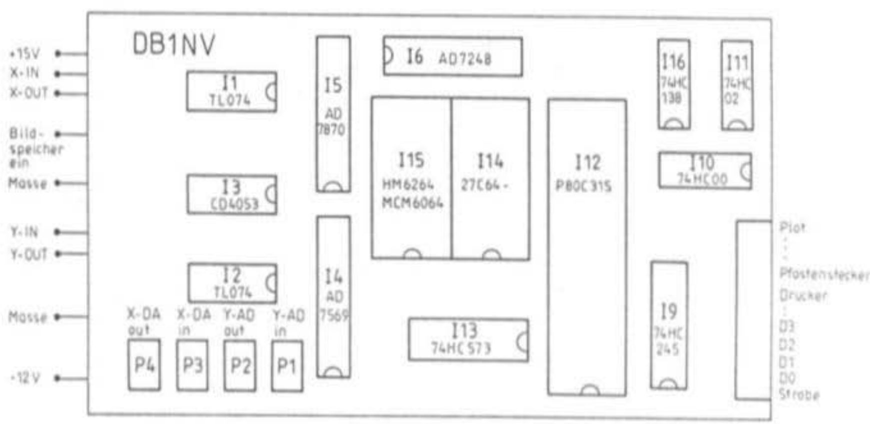


Fig.9: Suggested layout of ICs

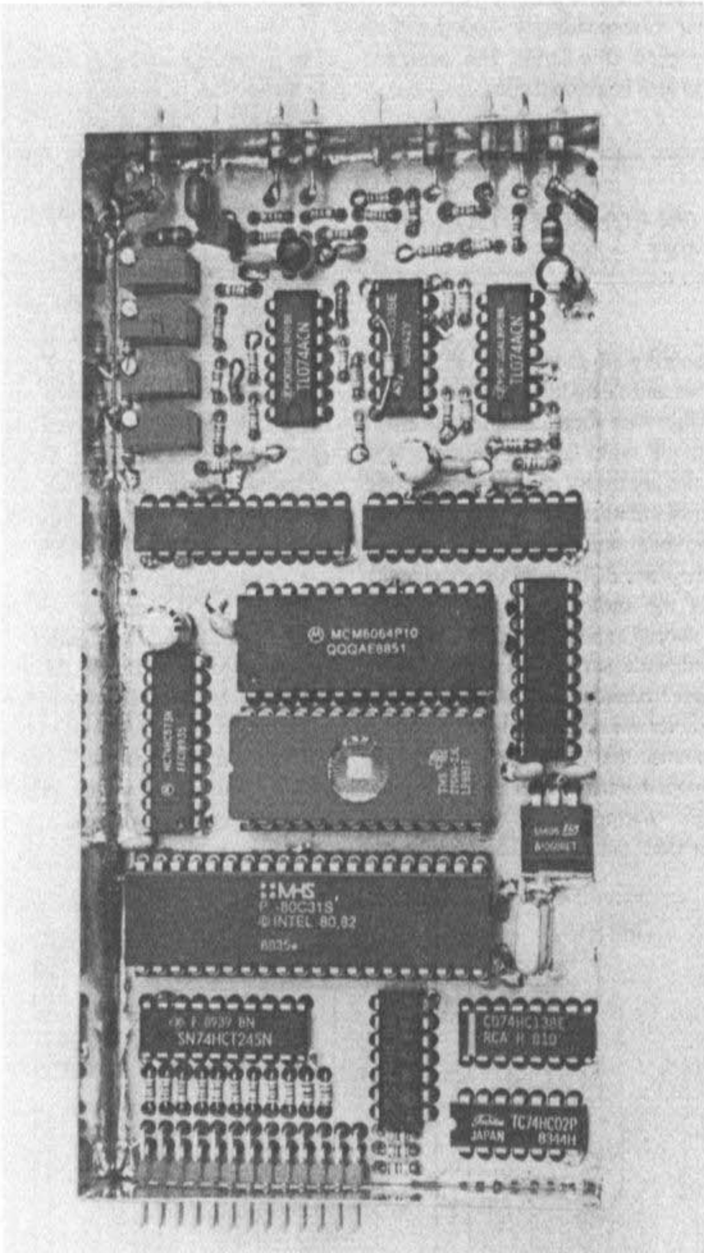


Fig.10: Sample construction of the digital image store. The TMS27C64-2 EPROM shown here was used only for the photograph

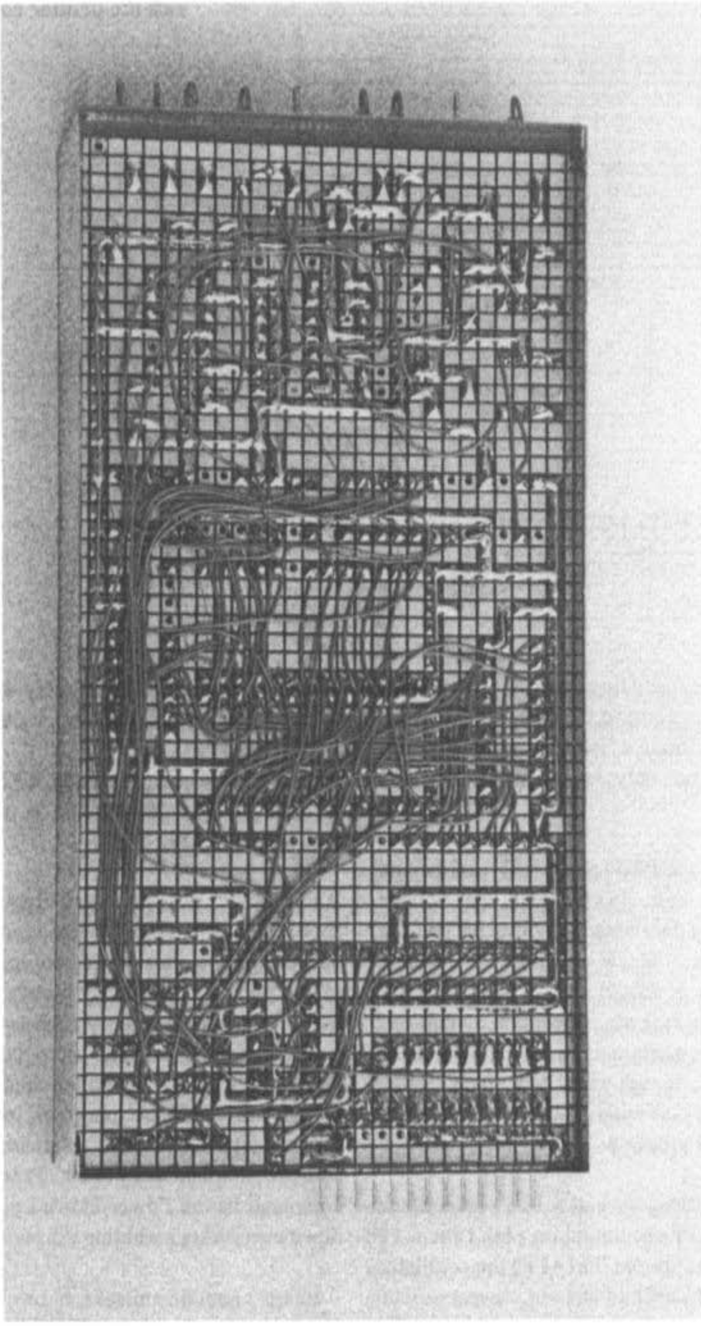


Fig.11: The hand-wired underside

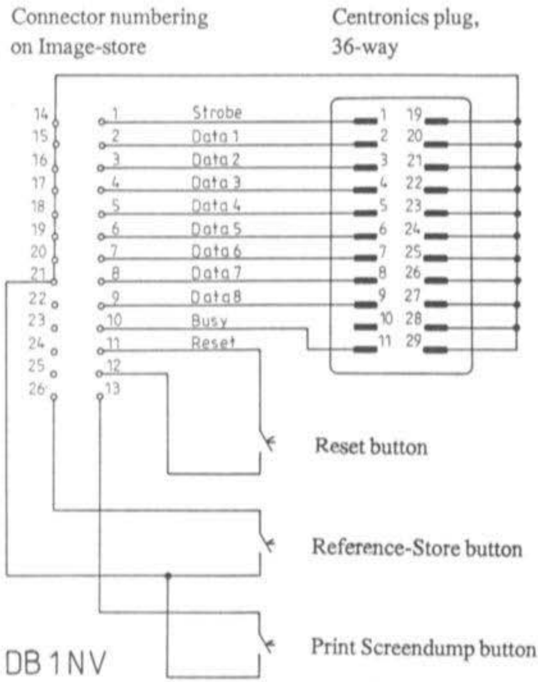


Fig.12: Wiring of the press-buttons and the printer connections

When you are ready to put the unit into service it is best to conform to the following scheme, which apart from a twin adjustable power supply requires only an oscilloscope and a voltmeter.

First connect the PSU to the +15V and ground connections, and slowly raise the voltage upwards from 5V. With the voltmeter you can check whether the 5V regulator is working. Current drawn should be at most 200mA, higher values indicate immediate switch-off. The same experiment is carried out with the -12V supply; if this goes well, then switch both supplies on firmly so that the microcontroller is reset properly.

With the oscilloscope and a 10:1 probe check can be made of oscillation on pins 18 and 19 of the 80C31. On pin 30 (ALE) the oscillator frequency divided by 6 is to be measured. The timer interrupt should be functioning now, measured as a short pulse every 40 uS at pin 17 of the AD7248 and as a sawtooth on pin 20.

If you ground pin 15 of the 80C31, similar pulses should be measurable at pin 24 of I5 and at pin 18 of I4.

If things have not gone quite right so far, you should check if there is any activity on the data bus. If not, check the reset circuit (is pin 9 of the 80C31 permanently high?). Should no oscillation be detected, try another crystal as a test. A frequent mistake is to leave pin 31 floating; the microcontroller then tries continually to fetch the program from a non-existent internal ROM. Miswired data or address lines can lead the 80C31 to interpret a command as the Power-Down code and shut down everything including the oscillator!

Another common mistake is to connect two inputs with one another: sometimes the

CMOS devices will work but then shut down at the approach of your hand. To find this situation or floating inputs the author uses a little trick circuit. The calibrator of the oscilloscope (approx. 1V p-p) is tied via 10K to the tip of the probe so that the calibration signal is visible. If you now touch the suspected points while the circuit is running, a normal CMOS output will pull the potential to +5V or ground, noted by the disappearance of the calibration signal. The small additional load is no danger for the circuit. Unwired inputs, however, will barely have any influence on the signal! This technique can be used with success in all CMOS circuits.

All other errors, like short circuits to +5V or ground, are found fastest with the ohmmeter.

If, contrary to expectations, everything goes smoothly, the image store can be connected into the signal lines between the spectrum analyser and the display unit. To begin with, only the Image Store On switch should be connected to ground.

When the switch is open, the signal paths are looped through and the analyser should work as before. Any problems can be found with the oscilloscope. Now P2 and P3 are turned hard to the left, and P1 and P4 adjusted to the centre of their range. The author incidentally used 10-turn potentiometers, which are easier to set than standard pots.

After switching to storage operation the first picture to appear will consist of "rubbish". First P4 (output voltage, X D/A converter) is used to set the frequency axis to the same length as in non-storage operation. Then P3 (input voltage, X A/D converter) is turned until the "rubbish" visible on the left-hand and right-hand sides of the screen disappears. Now you provide the input of the analyser with a signal producing a line which easily overloads the display screen. As standard values you can set the X deflection to 500kHz/cm and the filter bandwidth to 200kHz. Now P1 (input voltage, Y A/D converter) is adjusted so that the line is limited above. Finally adjust P2 so that the image height is equal in both storage and non-storage operation.

After installing the image store the task remains to make the wiring connections from the terminal block to the printer and the press-buttons for Reset and Screendump.

The author used a 25-pin D-Sub socket for the printer, as fitted on PCs. Following connection of an Epson-compatible printer the appropriate button is pressed and a printout of the screen content should follow. If only squiggly symbols appear, check the data lines for short circuits and that they have not been mixed up in wiring. It is also worth checking in the printer's handbook for any DIP-switches to set, e.g. to effect alternate mode on the HP Thinkjet. With unknown printers it is also worth checking the interface: it could be a serial printer and the 25-pin D-Sub connector is sometimes used for both types of printer. If the printer does not move at all, this is probably because the Busy line is permanently high. Alternately a permanent low on this line leads to buffer overflow in the printer; this can be recognised by the first part of the display printing correctly, then followed by wiggly symbols.

Many readers may find this description too detailed, but in the case of problems it is bound to be of use. Try asking a few PC experts what happens when this or that line to the printer is mixed with another, or is held high or low - you will be surprised!

If all the foregoing tests have been rewarded with success, then the image store is ready for operation. The three push-buttons are used as follows:

◆ the Reset button is the basic switch-on setting and cuts off other activities such as screendump and clears the image store

◆ the Screendump button starts the printing process

◆ the Reference button transfers the current spectrum to the store

◆ holding the Reference button down while pressing the Reset button briefly activates the averaging function.

In every case, pressing the Reset button is the same as first switching on the image store.

6. COMPONENT SOURCES

The microcontroller 80C31 with 20MHz operating speed is made by Matra-MHS and by AMD. Valvo (Philips) has even announced a 24MHz version, but the author has had no feedback on availability. The high-speed EPROM (less than 100nS) also comes from AMD. The A/D and D/A converters are to the best of the author's knowledge available only direct from Analog Devices. All other parts can be had at any good electronics store.

Programmed EPROMs and an IC set can be ordered from the publisher.

Matjaz Vidmar, YT3MV

DSP Computer Update Nr.1

Since the publication of the series of articles about the DSP computer in VHF-Communication (1) several changes to the original project occurred. Most of these are of course included in new and upgraded software.

There have been some minor changes to the hardware as well to allow for wider component tolerances, or to improve the performance of the circuit.

Therefore it was decided to write this short article just to describe all of the changes that occurred in the meantime and all of the new software that is already being distributed. Since at least the software is very likely to change and improve in the future, this article is intentionally kept as short as possible.

Future software changes will be handled in similar article updates.

1. SMALL HARDWARE MODIFICATIONS

1.1 The CPU Clock Frequency

Most DSP software runs much more efficiently upgrading the CPU clock frequency even by a small relative amount. The reason for this is that the DSP routines, being triggered by interrupts, require a precisely defined amount of CPU operations per time unit.

Most DSP software is designed to use around 80% of the CPU capacity at a clock frequency of 10MHz. Upgrading the clock frequency to 12MHz means that the remaining CPU capacity (less the fixed amount used by DSP routines) will be doubled if compared to the 10MHz performance.

Of course, increasing the CPU clock frequency requires appropriate hardware:

◆ The MC68010 CPU itself is available in three versions: 8MHz, 10MHz and 12.5MHz. Most 10MHz versions will work up to 15 or 16MHz clock, but each MC68010 has to be tested whether it can operate reliably at higher clock frequencies than specified, also at higher ambient temperatures.

◆ The 74HC00 used in the clock oscillator also affects the maximum frequency the CPU can achieve. All of the memories and peripherals also affect the maximum CPU clock frequency.

It is therefore recommended to upgrade the CPU clock to 12 or 13MHz. Some peripherals may not work reliably and the advantages of an even higher clock frequency are very small with existing software.

1.2 Automatic Tranceiver Doppler correction

Many modern transceivers have the facility to control the transmit and receive frequencies by remote control. It is now possible to achieve this function, to compensate for Doppler shift when tracking satellites, automatically when using the TRACK program.

The "AUX OUT" (port B) of the uPD71055 (or 82C55) is now being used as an output port by the program TRACK, so these active-high outputs provide the UP/DOWN pulses for automatic transceiver frequency adjustments.

Some 82C55 chips require a much higher value capacitor on pin 6 (CS) than indicated on the circuit diagram for correct operation: sometimes up to 1500pF!

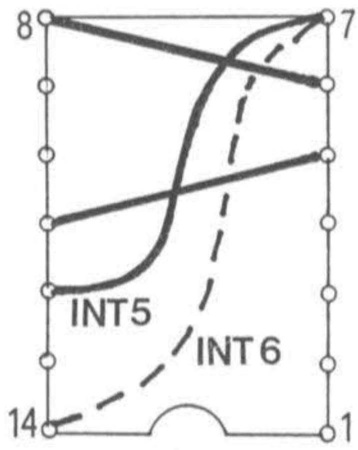


Fig.1 Rewiring the 8530 interrupt

1.3 Modifications to the Video Board

The video board also requires a few modifications for optimum performance. First, the 120pF capacitor from pins 5 and 8 of the 74LS02 (74HC02) may need to be decremented down to only 68pF for proper operation at higher CPU clock frequencies.

Further, the 74S374 used to drive the D/A converter may only be replaced with a 74F374, or, in the worst case, with a 74LS374. CMOS versions (73HC374 or 74AC374), although recommended elsewhere in the DSP computer, should not be used here, since the performance of the DAC0800 degrades with CMOS input levels.

Finally, the 1.5pF capacitor between pins 2 and 8 may be decremented, or totally eliminated, to obtain the best grey level transitions.

1.4 Modification for the Analog I/O

A single modification is suggested for the analog I/0 board. It was found very useful to increases the audio output impedance by increasing the original 820ohm resistors up to

22kohm. A higher output impedance decreases the disturbances that are otherwise picked-up because of ground-loop noise (mainly mains hum) by the MIC input of the transceiver.

1.5 Changes to the Serial I/O and the Disk Interface board

Finally, the serial I/O & floppy interface board requires a few jumpers to be moved to different positions. First, the 8530 interrupt should be rewired to INT5 in place of INT6 (Fig.1). This was found more suitable for the new software, which is also using the serial I/O port.

Secondly, DS1 should also be wired on the corresponding socket if a second floppy drive is installed. This second drive can not be accessed by the present operating system, it can only be used by some application software.

2. UPGRADED AND NEW SOFTWARE

2.1 The Operating System

The operating system software has not been modified much: the latest version is 7.3. and it still resides in a 16kbyte EPROM. It is upwards-compatible with all the existing software and hardware for the DSP computer.

All of the software supplied on the floppy disks should however be used exclusively with the latest version (actually 7.3) of the operating system!

A revised manual for OS 7.3 is also available.

2.2 The TRACK program

TRACK had several additions:

- Sun and Moon ephemeris are now built-in under the options 41 and 42.

- The satellite predictions now include more parameters: the longitude and latitude are displayed too.

The new version of TRACK is also able to control the frequencies of three independent receivers and/or transmitters to compensate for the doppler shift automatically. The program will supply correction UP/DOWN pulses on the outputs 00/01, 02/03 and/or 04/05 of the AUX OUT port, corresponding to link 1,2 and/or 3 frequencies. The frequency step(s) used by the receiver(s) and/or transmitter(s) can be adjusted in menu 45. Steps have to be larger than 10Hz. Negative steps will reverse the direction of the frequency converter, or to compensate the doppler shift on the uplink. The tuning rate is further limited to 1kHz per second (if the steps are smaller than 1kHz) and to a maximum doppler shift of +/-300kHz.

The new version of TRACK is also able to automatically load the keplerian orbital elements from an ASCII file. Orbital elements are however available in many different formats. TRACK accepts orbital data in the "UOSAT" format, which contains all of the data in a single text line starting with the satellite name and followed by numerical parameters. TRACK is also able to generate an ASCII data file in the same format containing the orbital elements for all 40 satellites.

To handle other data formats two separate programs are supplied with TRACK: NASAKEP and AMSATKEP. NASAKEP will translate the "NASA 2-LINE" orbital elements into the "UOSAT" format, also computing the checksum and marking bad data sets with a 2*''. AMSATKEP will translate the ''AMSAT'' orbital elements into the appropriate format for TRACK. The resulting data file KEPLER.DAT will probably require some modifications, at least to eliminate unwanted satellites. This can be done easily using the operating system text editor ''Y'' and/or command ''C'' to merge more data files together.

2.3 The RTTY Software

RTTY now includes both reception and transmission in the same format as specified in the main menu. Switching between reception and transmission is performed with the ''LineFeed'' key for manual transmission or ''#'' command to send a prepared text file. In BAUDOT mode the program will print all of the ASCII characters found in the text file that is being transmitted, but it will not be able to translate all those characters into the BAUDOT code for obvious reasons. Another modification to RTTY is the elimination of the squelch line: RTTY now ignores the squelch input.

2.4 The FFT Program

FFT has a bug that has not been corrected yet: with very large input signals (over 2Vpp) the FFT algorithm may overflow in the weighted mode. This appears as a sudden change to the display that includes a very large number of inexistent spectral lines. The solution is to check each time the input signal level, since the A/D converter corrupts too large signals anyway.

2.5 AX25 and MAX25

The Packet radio programs AX25 and X25 only had a few minor changes, to remove a few bugs and optimize the protocol.

2.6 The PSK1200 Program

PSK1200 now supports full-duplex operation, so the set of parameters has been increased to better define the switching of the transmitter on the off. PSK1200 includes two different PSK demodulators:

◆ The ''LIMITING PLL'' demodulator is identical to the one in the old PSK1200 program.

```
### YT3MV - NOAA HRPT receive & display - 31/12/1990 ###

 1 RECEIVE & DISPLAY PICTURE

 2 Picture data file:   NOAA10      .IR   819712 bytes = C8200H
 3 Tracking data file:  TRACK       .DAT     138 bytes = 8AH
 4 Gridding map file:   EUROPE      .ELM   42876 bytes = A77CH

Start:NOAA-10    UTC: 18 41 20 / 20  2 1991   3.2E 31.0N  818km  7.4km/s 349.9deg
End:  NOAA-10    UTC: 18 43 33 / 20  2 1991   0.9E 38.7N  816km  7.4km/s 348.9deg

PICTURE FORMAT:    5 pixels/line:  1024        6 lines/picture:   800

RECORDING:    7 pixel rate:  1.00      8 start pixel:   512      9 line rate:  1.00
Grey-scale compression:    10 gain:  1.00        11 black level:     0

DISPLAY:        12 pixel rate:  2.00     13 start pixel:      0
                14 line rate:   3.10     15 start line:       0
Grey-scale enhancement:    16 gain:  2.50        17 offset:         106

AUTOSTART:    18 start time: 12.00      19 time window: 720.0 minutes
20 longitude:  10.0E      21 window:  22.0    22 latitude:  35.0N    23 window:   4.0

GRIDDING:     24 along-track:    -5     25 cross-track:     10     26 shape:  2.50

FLAGS:     27 scan: CORR       28 display: UP        29 video: TRUE      30 start: AUTO

31 set defaults        · 32 reset start-end data
 0 or carriage return = exit

Enter option number / add parameter :
```

Fig.2: The main HRPT Program menu

◆ The "COSTA LOOP" demodulator offers a better performance, but requires a higher CPU clock frequency.

PSK1200 is designed to operate with the JAS-1B (FO-20) mailbox or other standard packet-radio protocol communications. The Microsats use a non-standard protocol and require special software.

2.7 TLM1200 BDECODE and WEBERPIC

TLM1200 includes both PSK demodulators of PSK1200 and was designed especially to receive the telemetry from the Microsats. It can display and record the packets received in both ASCII and HEX. Further, the single packets can be tagged with data from TRACK (satellite name, position and time) if so desired. The received packets can be assembled in a file and processed by BDECODE or WEBERPIC.

BDECODE decodes the bulletin broadcasts from PACSAT and assembles the corresponding files.

WEBERPIC assembles the CCD camera pictures transmitted by WEBERSAT (WO-18).

2.8 The Program BPSK400

Both BDECODE and WEBERPIC require the bulletin broadcasts from PACSAT and assembles the corresponding files. WEBERPIC assembles the CCD camera pictures transmitted by WEBERSAT (WO-18).

Both BDECODE and WEBERPIC require the data to be received by TLM1200 and recorded in the HEX format.

BPSK400 was modified to provide a much better display. The data is formatted to 64 columns as specified for AO-13 and each block can be tagged with data from TRACK (satellite name, position and time). Three reception modes are possible: raw ASCII, framed ASCII (showing only blocks) and HEX.

2.9 APT and WEFAX

APT and WEFAX have not been modified yet, although many modifications are imminent. WEFAX should be modified to decode the new Meteosat digital image header while APT will be probably completely rewritten using the new program HRPT (described below) as a reference.

To print both APT and WEFAX pictures on standard APT hardcopy devices the program TXAPT was developed.

2.10 TXAPT, SCREEN and LSCREEN

TXAPT is a Terminate-and-Stay-Resident (TSR) program that disappears after being executed. When recalled by depressing <CTRL-DEL> it will, however, transmit the screen content as an APT picture with a 300Hz start tone, standard sync pulses and 450Hz stop tone at 240 lines per minute, 2400Hz AM subcarrier, through the analog output port. TXAPT will however reprogram and finally reset the analog port, so it will stop any real-time operation of WEFAX or APT.

SCREEN an LSCREEN are also TSR programs recalled with <CTRL-DEL>. They will, however, generate a screen hardcopy file that is understood by most dot-matrix computer printers. The two programs will generate two different-size files for two different sizes of the hardcopy, of course black-and-white only and with black and white exchanged. When using TSR programs one should avoid to use the operating system "K" instruction before exiting from the TSR program with the "Q" operating system instruction.

2.11 The Program HRPT

HRPT is a program to receive and display NOAA HRPT pictures. The latter are transmitted in the 1.7GHz band form NOAA and FengYun type satellites in a digital format at 665.4kbps.

Of course, the DSP computer can not demodulate such fast digital transmissions: an external receiver, bit-rate synchronizer, frame synchronizer and interface are required. The DSP computer is used to store and display the pictures.

HRPT features automatic start of picture recording, advanced zooming and grey-scale enhancement and picture gridding, adding coastlines, borders and geographical grids to the image. The main menu of HRPT is shown on Fig.2.

HRPT requires three additional files: a picture storage file, a tracking data file(TRACK.DAT) and a map file (EUROPE.ELM). The picture file includes a 512 byte picture header with all the necessary data for geometrical corrections and picture gridding. Picture data and organized as a number of picture lines with one byte assigned to each pixel.

Fig.3. shows the interface between a NOAA HRPT bit & frame synchronizer and the DSP computer. The interface selects one of the five HRPT spectral channels and transmits the original 10-bit pixels as two consecutive 6-bit words at 384kbps to the DSP computer serial I/O port, channel A (RXD). The interface includes 8 DIP switches to adjust the frame pulse phasing with respect to the synchronous 10-bit words and select the desired spectral channel. The interface is built on a small double-sided printed circuit board (55 x 120 mm, Fig.4.).

2.12The program HARDCOPY

HARDCOPY is a TSR program that produces a 25 grey-level picture of the computer screen on a laser printer. The actual version of HARDCOPY is designed for the EPSON GQ-3500 laser printer and sends the data through the RS-232 port at 19200bps to the printer immediately after <CTRL-DEL> is depressed. Due to the low RS-232 speed it takes about three minutes to obtain a screen hardcopy in this way. HARDCOPY uses the maximum printer resolution of 300dpi. A4 x 6 printer pixel field is assigned to each DSP computer screen pixel thus yielding 25 possible grey shades including black and white. HARDCOPY can produce excellent results if used together with an image-processing program like HRPT: see Fig.5 and Fig.6 which were obtained with HRPT and HARDCOPY.

2.13 DTRACK

DTRACK is very similar to TRACK but modified for NOAA (FengYun) HRPT reception. It includes a special DSP routine to measure the doppler shift and automatically correct orbital data.

This is very necessary with NOAA HRPT for two reasons: the beam of the 1m diameter receiving dish at 1.7GHz is so narrow that a time error of just 15 seconds causes loss of data, and the HRPT gridding routine requires even more accurate data about the exact satellite position.

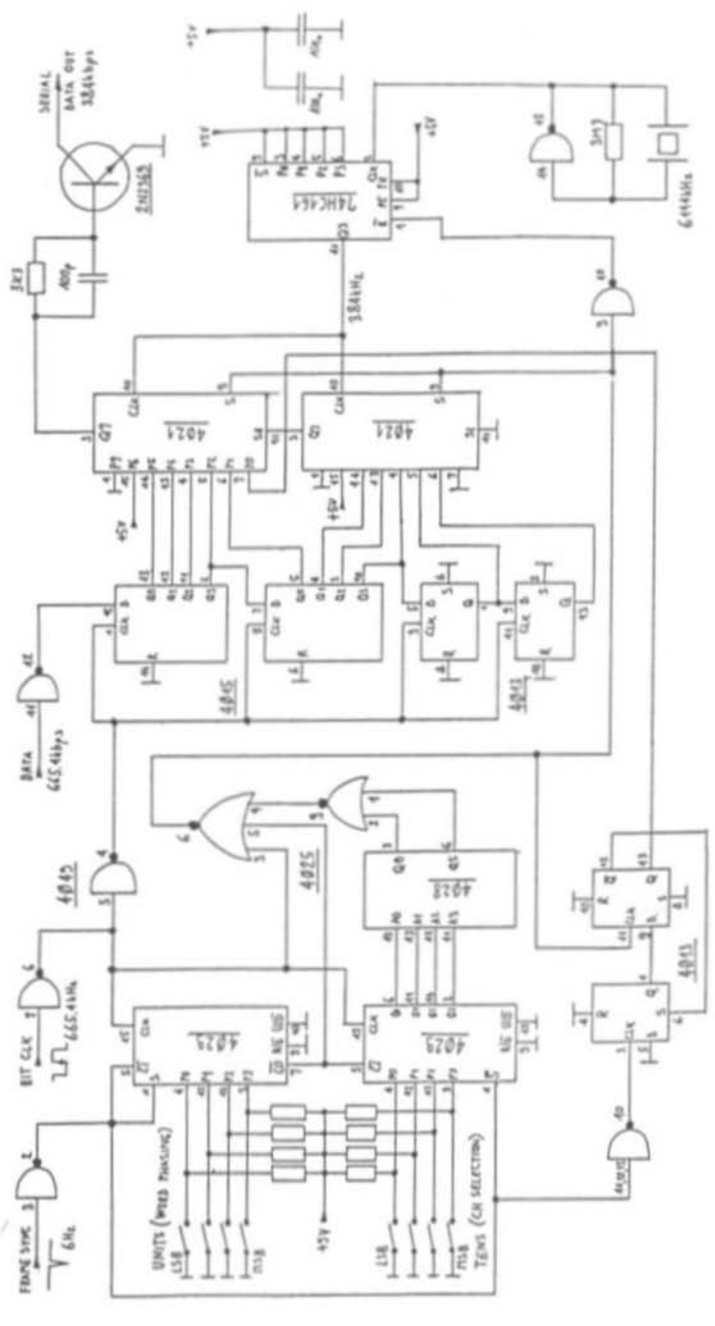


Fig.3: The Interface between a NOAA HRPT bit and frame synchroniser and the DSP Computer

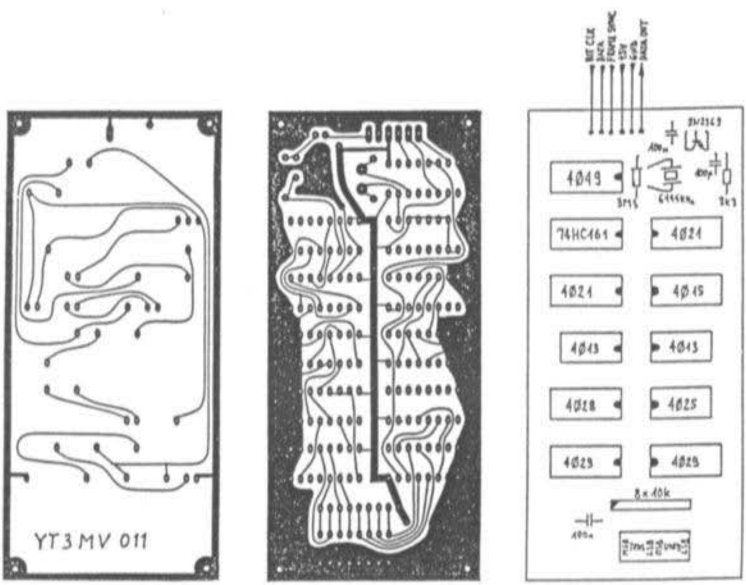


Fig.4: PCB Layout and Component Overlay for the HRPT Interface - YT3MV-011

DTRACK measures the doppler shift on the regenerated HRPT bit clock of 665400Hz, so that no modifications are required in the HRPT receiver. The bit clock has to be downconverted to about 333Hz using a very stable reference oscillator (TCXO) and then fed to the analog input of the DSP computer.

A lock signal has to be derived from the HRPT receiver and fed to the squelch input to enable the internal DTRACK routines to operate correctly.

DTRACK is actually an experimental program and it will probably be replaced by a more sophisticated program designed especially for HRPT tracking.

If HRPT and DTRACK are used together, they require a 12MHz minimum CPU clock frequency!

3. FUTURE PROJECTS

3.1 Hardware

1Mbit static RAM chips are readily available on the market and their prices are competitive to the 256kbit chips used in the DSP computer. The next hardware upgrade will be higher density memory boards using these new devices, allowing much higher resolution satellite pictures to be stored in the DSP computer memory.

3.2 Software

On the other hand it is difficult to predict future software upgrades. Modifications and improvements to the current APT and WEFAX programs are most likely, together with a new program to receive Meteosat HR

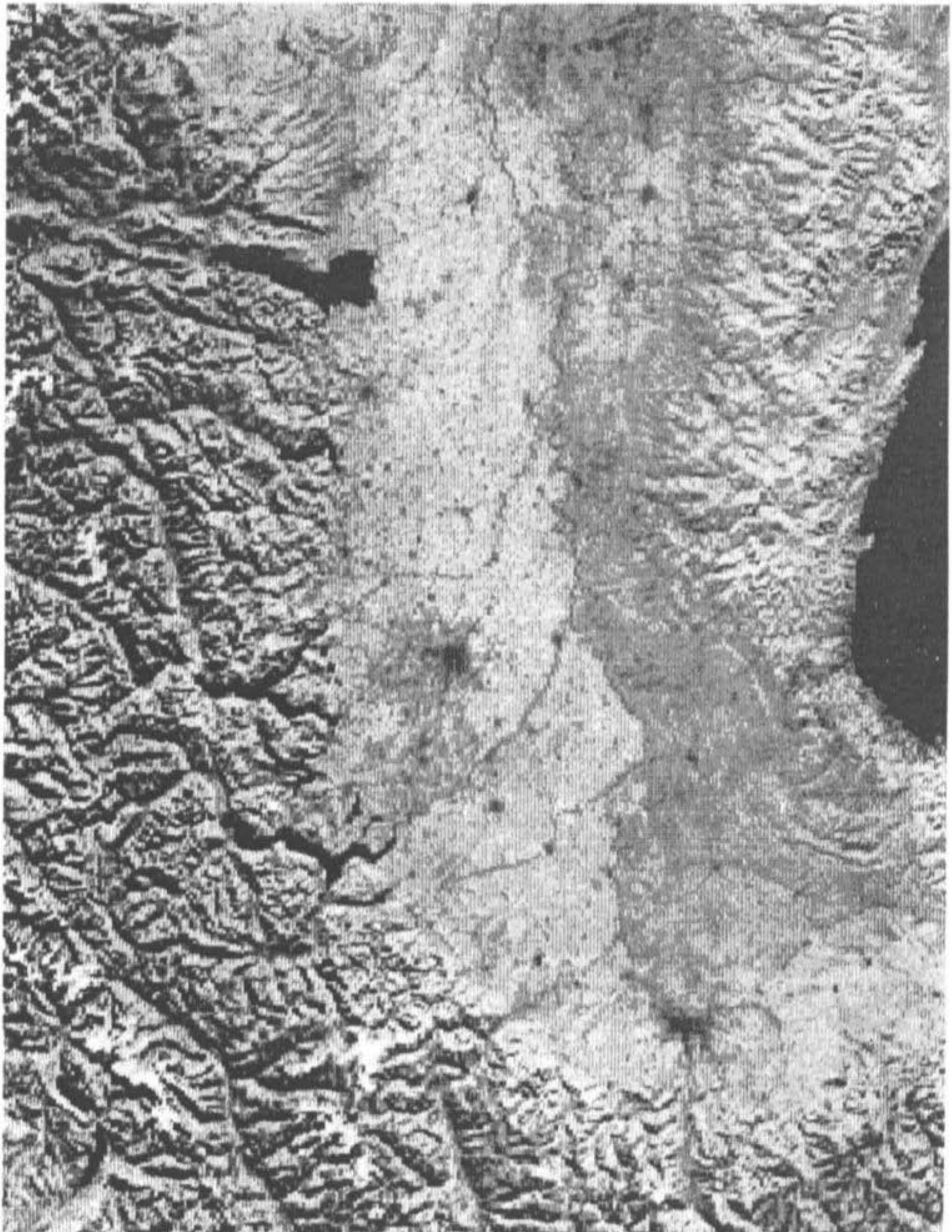


Fig.5: An HRPT picture from FengYun-1B, chn. 2 (VIS), 12th Sept 1990 (1695.5MHz)

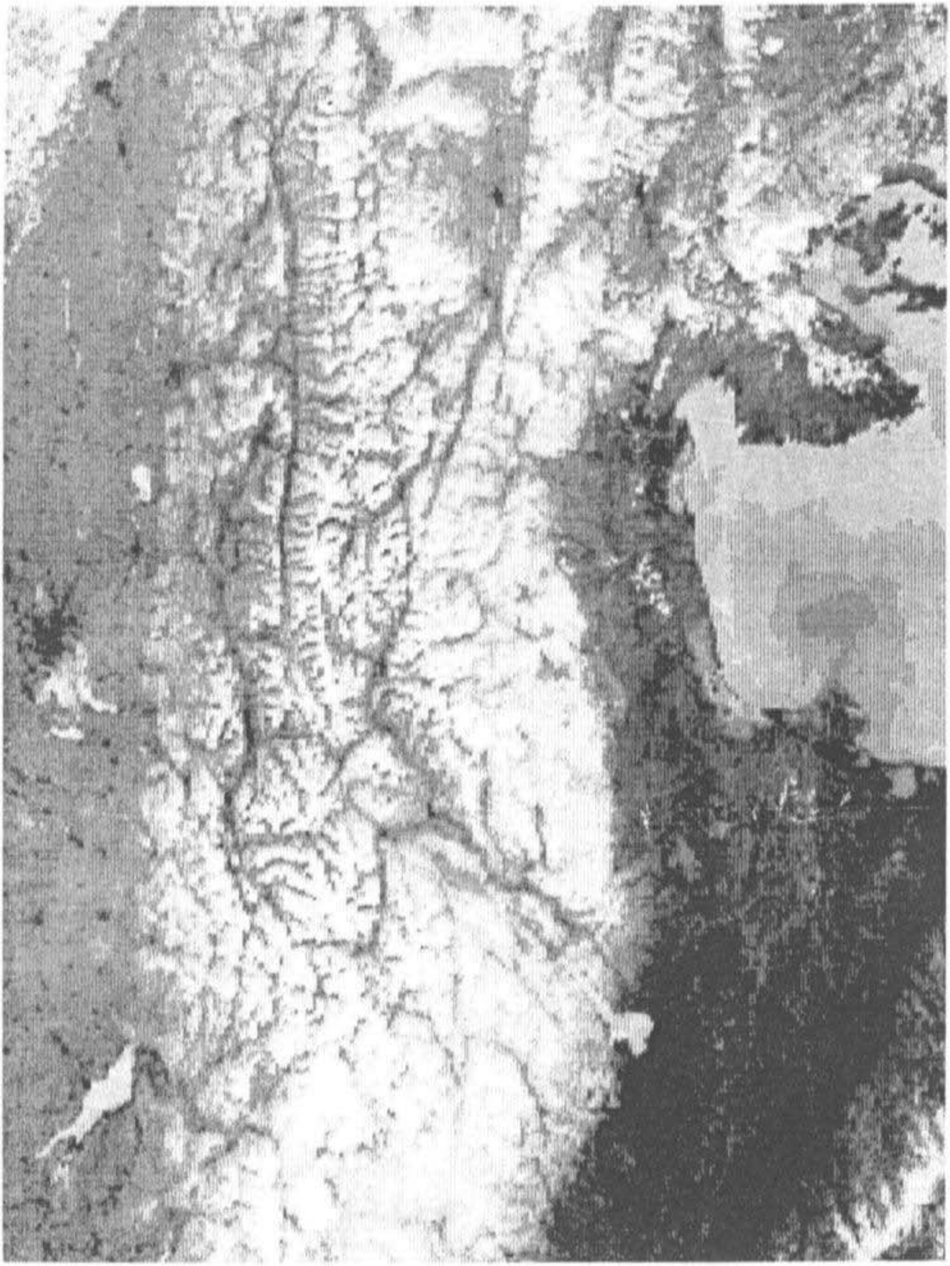


Fig.6: An HRPT picture from NOAA-11, chn.4 (IR), March 26th.1990, (1707MHz)

images (of course with the appropriate receiver, bit & frame synchronizer and interface).

3.3 Global Positioning System

A completely new project is a Global Positioning System (GPS) receiver. GPS is a very accurate navigation satellite system. Each satellite also carries a caesium atomic clock and each user has thus access to a time/frequency standard in the accuracy range of 1 part in 10^{12}.

A GPS receiver relies heavily on digital signal processing. A two-channel GPS receiver was developed also for the DSP computer and it will be described in detail if there is sufficient interest.

Finally, I want to mention that readers' feedback is expressively encouraged: many of the modifications and improvements to the DSP computer software presented in this article were proposed by readers that built the DSP computer.

4. LITERATURE

(1) Matjaz Vidmar, YT3MV: Digital Signal processing techniques for Radio Amateurs.
VHF Communications 2/88 pp 76-97 Theory
VHF Communications 1/89 pp 2-24 Part 2
VHF Communications 2/89 pp 74-94 Part 3
VHF Communications 3/89 pp 130-137 Part 4a
VHF Communications 4/89 pp 216-227 Part 4b

(2) Matjaz Vidmar, YT3MV: Amateur radio applications of the Fast Fourier Transform.
VHF Communications 2/90 pp 123-126 Part 1
VHF Communications 3/90 pp 130-138 Part 2a
VHF Communications 4/90 pp 219-229 Part 2b

Wolfgang Schneider, DJ8ES

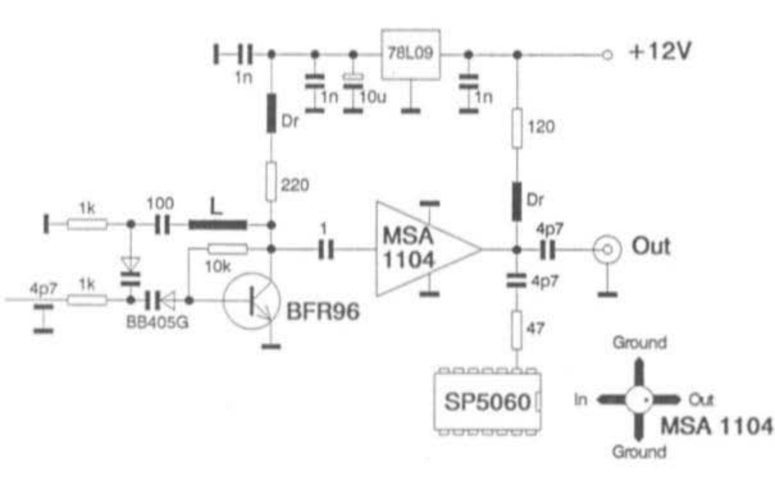
Modification of the FM-ATV Transmitter DD2EK 002

Increasing the output power to 50mW

Thanks to the continuing development of MMICs (Monolithic Microwave Integrated Circuits), the constructor has a choice of modules in the 50-ohm technology that work up into the GHz region. If we change just two of the elements, the FM-ATV transmitter DD2EK 002 (1) can now deliver an output power of 50mW.

1. CIRCUIT CHANGES

In the circuit the broadband amplifier MSA0404 is replaced by the newer type MSA1104 (2). In the 23cm band this MMIC



provides 50mW output power with an amplification of 9dB and a current requirement of 60mA.

The power supply of the amplifier needs to altered to meet the new requirements. The 100-ohm resistor between the choke (Dr) and the 9V regulator circuit is removed. In its place we put a 120-ohm 0.5W resistor; this leads from the choke straight to the 12V supply rail.

2. OPERATION

No new alignment is needed for this alteration. With a 12V supply it will produce 50mW at the output. For the author a single stage hybrid amplifier M57762 (3) connected in cascade and also fed with 12V raised this signal to 2.2W.

3. LITERATURE REFERENCES

(1) Wolfgang Schneider, DD2EK: FM-ATV in the GHz Region; part 1: FM-ATV transmitter for the 23cm band. VHF Communications 1/89 pp 25-30.

(2) Avantek data sheet MSA1104.

(3) Joachim Berns, DL1YBL: Linear amplifier for the 24/23cm band . VHF Communications 4/89 pp 211-215.

Robert E. Lentz, DL3WR

HP AppCAD - A Software Collection for Calculating Microwave Exercises

The keen response to my description of the CAD software "Puff" (1) encouraged me to take note of a further PC program which is interesting and helpful: HP AppCAD.

HP AppCAD comes on three 360K diskettes, which contain a comprehensive selection of HP semiconductor data and calculation programs for commonly-occurring microwave problems.

Fig. 1 shows the main menu. As you move the cursor on the left-hand side of the screen from line to line, a brief description appears on the right (Fig.2).

```
Hewlett-Packard                   Main Menu                          AppCAD

      Select From Menu:
                                               AppCAD
   Transistor Design Data
   Mixer Spurious Search                    Version 1.02
   Microwave Calculator
   Microwave Path Calculations
   Transmission Lines                 Hewlett-Packard Co., 1990
   Two-port Circuit Analysis            All rights reserved
   Spiral Inductor Design
   Impedance Matching
   PIN Attenuator and Switch Design
   Schottky Detector Calculations
   Transistor Bias Circuits
   NoiseCalc
   Thermal Analysis
   Product Selection Guide              HP Part No. HAPP-0001
   Literature Request
   Sample Request                 Application Engineering Staff
   Register for Updates          Microwave Semiconductor Division
   For More Information...

   F1 =Help                                       ESC =Return to DOS
Use the arrow keys to highlight desired item and press return to select
```

Fig.1

```
Hewlett-Packard                      Main Menu                              AppCAD

      Select From Menu:                      ■ Microwave Path Calculations

   Transistor Design Data                      This module calculates the S/N
   Mixer Spurious Search                       system performance resulting
   Microwave Calculator                        from these factors:
 X Microwave Path Calculations X
   Transmission Lines                          ■ Receiver noise figure
   Two-port Circuit Analysis                   ■ Antenna gain
   Spiral Inductor Design                      ■ Transmitter power
   Impedance Matching                          ■ Path distance
   PIN Attenuator and Switch Design            ■ Frequency
   Schottky Detector Calculations              ■ Line losses
   Transistor Bias Circuits
   NoiseCalc                                   Systems Covered:
   Thermal Analysis
   Product Selection Guide                     ■ One-way (Communication)
   Literature Request                          ■ Two-way (Radar)
   Sample Request
   Register for Updates
   For More Information...

   F1 =Help                                          ESC =Return to DOS
   Use the arrow keys to highlight desired item and press return to select
```

Fig.2

```
Hewlett-Packard                Communications System                     AppCAD

   XMTR ——/\/\/\——                                        ——/\/\/\—— RCVR ——o
        Cable Loss                                          Cable Loss

   Power Out: 100   W      Dist: 999  Km      Ant Noise Temp: 90.0  ºK
  Cable Loss: 0.1   dB     Freq: 2.4  GHz       Antenna Gain: 19.0  dB
Antenna Gain: 10.0  dB                            Cable Loss: 1.0   dB
                                               Receiver Gain: 24.0  dB
                                                 Receiver NF: 1.2   dB
                                                   Bandwidth: 2.4   KHz
                                               2
         Effective Radiated Power:   9.8 X 10   Watts
                                              -11
              Power at Rcvr Input:   0.6 X 10   Watts

            Rcvr Noise Temperature:  92.3 ºK

           S/N Ratio at Rcvr Output:  59.0 dB

       F1 =Help    F2 =Compute    F3 =Units    ESC =Quit
               Enter transmitter antenna gain.
```

Fig.3

```
Hewlett-Packard                Microwave Calculator                       AppCAD

  — Mismatch Error Limits —            ——————— Reflectometer ———————

      SWR1 = 1.15                      Coupler Directivity = 35 dB
      SWR2 = 2.10
                                                          Min   Meas   Max
    Max  SWR       2.42
                                                   SWR   1.78   1.86   1.93
 Max Phase Error  ±  1.42 deg           Refl Coefficent  0.28   0.30   0.31
                                      Return Loss (dB) 10.96  10.43   9.94
   Max Mismatch   + 0.212 dB        Mismatch Loss (dB)  0.36   0.41   0.36
      Error       - 0.217 dB

  ———— dB to Ratios ————               ———— Conversion Table ————

        dB = 6.00                               SWR =  1.81
                                          Refl Coeff =  0.28
  Voltage Ratio = 2.00 E 00              Return Loss = 10.80 dB
    Power Ratio = 4.00 E 00            Mismatch Loss =  0.37 dB

       F1 =Help    F2 =Compute    F3 =Toggle    ESC =Quit
  Use the arrow keys to highlight desired item and press return to select
```

Fig.4

Hewlett-Packard PIN Attenuator and Switch Design AppCAD

This module performs some basic calculations relating to PIN diode switch and attenuator design. For switch design, insertion loss and isolation are computed from typical diode parameters. For attenuators, resistor values and the power dissipated in those resistors (PIN diodes) are computed.

Begin by making a selection from the menu below.

X Series Switch X
Shunt Switch
Pi Attenuator
Bridged Tee Atten

ESC =Quit

Fig.5

Hewlett-Packard Series Switch Design AppCAD

* Use Pg Up and Pg Dn to scroll the diode catalog

Hewlett-Packard Pin Diode	Rs (OHMS)	§ If (mA)	CT (pF)	§ Vr (V)	Package
5082-3304	0.9	100	0.300	50	CERAMIC

Frequency (GHz) = 2.40

System Zo (ohms) = 50

Insertion Loss (dB) = 0.07

Isolation (dB) = 7.7

F1 =Help F2 =Compute ESC =Quit
Enter frequency for isolation computation.

Fig.6

Hewlett-Packard Microwave Semiconductor Division AppCAD

The Hewlett-Packard Selection Guide is a menu driven program designed to help the user in selecting the correct part for a particular application. Catalog information current as of January 1990.

Selection Guide Main Menu

Schottky Diodes
PIN Diodes
Step Recovery Diodes
Noise Diode
X Transistors
Hybrid Amplifiers
Silicon MMIC Amplifiers
GaAs MMIC Products
Hi-Speed Decision Circuit
Integrated Products

ХESCÜ Quit Selection Guide
Use the arrow keys to highlight desired item and press return to select

Fig.7

After clicking there then appears, for example, a circuit of a communication system with characteristic data, of which one can enter one or more data and the rest is then calculated by pressing F2 (Fig.3). This happens in a twinkling!

Pressing F1 causes explanatory text to appear, with F3 you can change units - for instance between km, nmi and smi, or between kHz, MHz and GHz, or between mils and micrometres.

In the communication system in Fig.3 it happens that a maximum distance of only 999km can be entered. Anyone wishing to calculate satellite path distances will have to double the distance several times and use some mental arithmetic (2).

The "Microwave Calculator" (Fig.4) comprises four independent modules for calculating or recalculating commonly used values.

Clicking "PIN Attenuator and Switch Design" involves more effort. With the brief explanation pops up a selection window (Fig.5); clicking on "Series Switch" brings up a brief data sheet from which you can turn up the appropriate PIN diode from the HP

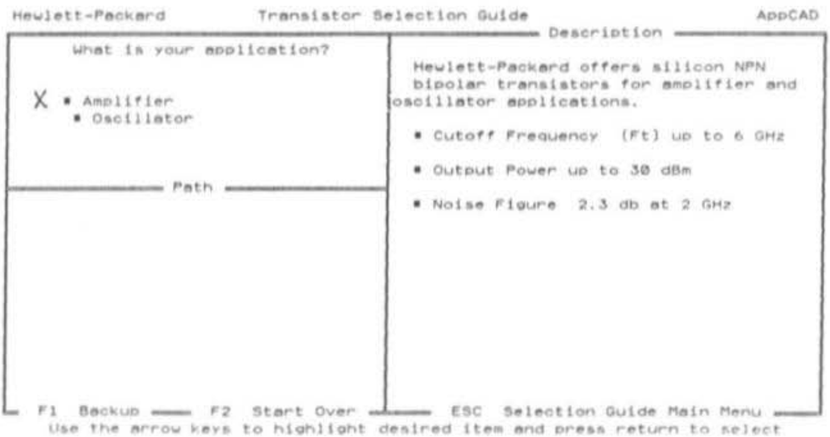


Fig.8

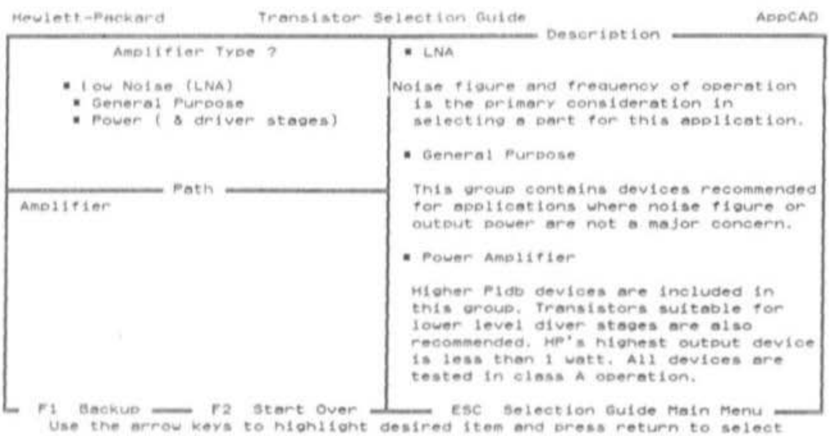


Fig.9

Hewlett-Packard Transistor Selection Guide AppCAD

Package Type ?

- Low Cost Ceramic
- Ceramic
- Surface Mount
- X Plastic
- Chip

Path

Amplifier
- Low Noise
- Max Frequency is: 2.4 GHz

Description

• Low Cost Ceramic

This is a hermetic high volume 100 mil package (100x) with tin plated leads.

•Ceramic

This includes the HPAC-100 and HPAC-70 packages with gold plated leads. Both are hermetic packages.

• Surface Mount

Includes SOT-143 and SOT-23 non-hermetic packages for automatic insertion equipment.

• Plastic

Includes the 85 mil diameter stripline packages (HPAC-86/85).

F1 Backup — F2 Start Over — ESC Selection Guide Main Menu

Fig.10

Hewlett-Packard Transistor Selection Guide AppCAD

» Recommended Device(s):

HXTR-3685

Path

Amplifier
- Low Noise
- Max Frequency is: 2.4 GHz
- Plastic

Description

• Package: Plastic Stripline (HPAC-85)

• Electrical Parameters

P/N	NF dB	GA dB	P1dB dBm	G1dB dB
HXTR-3685	1.8 typ	16.4 typ	16.3 typ	13.3 typ

Noise figure is at 1 GHz and Vce = 10V, and Ic = 10 ma. P1dB is at 1 GHz , 10V 15 ma. The device is also available in the HPAC-86 with similar electrical specs. The HXTR-3686 has the leads formed for surface mount applications.

See catalog for outline drawing.

F1 Backup — F2 Start Over — ESC Selection Guide Main Menu

Fig.11

Hewlett-Packard NoiseCalc AppCAD

INTRODUCTION

This module calculates various performance parameters for a sub-system block diagram such as a receiver. This type of analysis allows system planning for the tradeoffs of important characteristics such as noise figure (sensitivity), gain distribution, dynamic range, signal levels, and intermodulation products. A sensitivity analysis is also provided to assess individual stage NF and Gain contributions to overall NF. System performance may be evaluated at different temperatures with the input of temperature coefficients for NF and Gain for each stage.

Page 1

Enter Start Calculation

PgDn Next page Esc AppCAD Main Menu

Fig.12

Hewlett-Packard 2 - 22 - 1991
AppCAD NoiseCalc (v1.02)

Title:________________________________

Stage:	1	2
Noise Figure (dB)	1.00	5.00
Gain (dB)	15.00	-6.00
IP3 (dBm)	0.00	16.00
dNF/dT (dB/deg C)	0.000	0.000
dG/dT (dB/deg C)	0.000	0.000

Sys. Temp (deg C) 25.00 Reference Temp. (deg C) 25.00
Input Power (dBm) -30.0 Noise Bandwidth (MHz) 1.000

	1	2
Pout (dBm)	-15.0	-21.0
dF/dFi (dB/dB)	0.95	0.08
dF/dGI (dB/dB)	-0.05	0.00

Cascade Noise Figure (dB) 1.23 Cascade Gain (dB) 9.00

Noise Temperature (deg K)	94.9	Input IP3 (dBm)	-15.0
Signal-to-Noise ratio (dB)	82.8	Output IP3 (dB)	-6.03
Spur Free Dynamic Range (dB)	65.2	IM3 O/P Level (dB)	-50.95
Nominal Detectable Sig. (dB)	%-112.8		

Fig.13

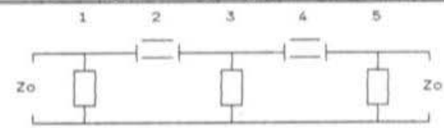
Hewlett-Packard Two-Port Analysis AppCAD

Units: DEG OHMS / MIL nH / GHz pF

Sweep: Start: 2.0 / Stop: 18.0 / Step: 0.25

Term: Zo: 50 — Filename — FILTER2

Output: DB S11 & DB S21 / X: 2.0 To 18.0 By 2.00 / Y: -40.0 To 10.0 By 10.00



1	2	3	4	5
49.70	43.90	49.70	43.90	49.70
90.00	90.00	90.00	90.00	90.00
9.00	9.00	9.00	9.00	9.00

F2 =Analyze F3 =Toggle F4 =Add F5 =Insert F6 =Delete F9 =Window
F1 =Help F7 =Read File F8 =Save File ESC =Quit
Press F3 to toggle angle units.

Fig.14

catalogue (Fig.6). After entering the working frequency and the impedance, the appropriate insertion and isolation attenuation values appear.

Much more comprehensive is the "Product Selection Guide". Here the choice is very broad (Fig.7) and after clicking you are led down a route (Figs.8, 9, 10) until finally one or more semiconductors for the frequency entered appear with their short-form data (Fig.11).

I printed out figures 1 to 12 using "Print Screen"; there are, however, also a pair of modules which contain their own print option. So for example the "Noise Calculation" (Fig.12): using F5 you can print out the calculation sheet with the values entered and the results calculated (Fig.13).

The module "Two-port Circuit Analysis" permits the analysis of linear circuits with concentric or distributed circuit elements, which can be chosen from a pop-up menu. In addition data of S parameters in Touchstone format can be entered as a circuit element. For the dipole - (Fig.14) shows one of two permanently installed examples - after matching the values and units or even altering the

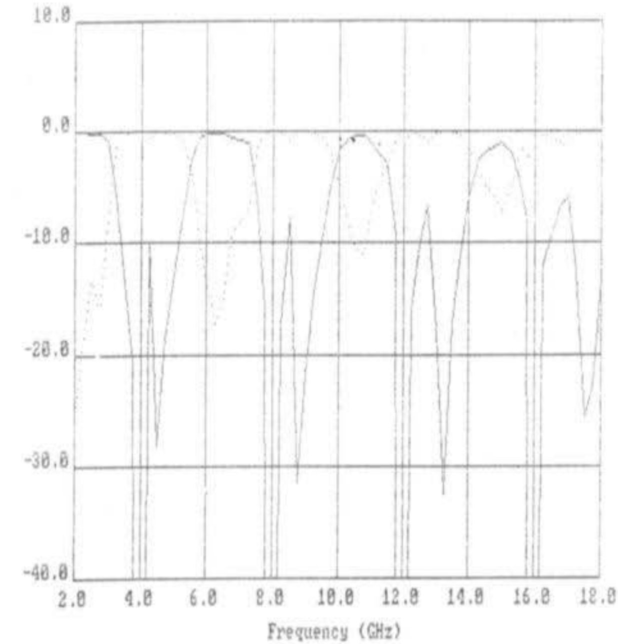


Fig.15

dipole itself, you can work out the values of S11 and S21 over the (fixed) range of 2 to 18GHz and print this in graphic form on paper using an Epson-compatible printer (Fig.15).

With this I have certainly not described all that HP AppCAD can do but at least a profile of it. It is probably clear that you need a good technical grounding: in my opinion, while the help files give useful assistance, they are no substitute for textbooks and reading. For printed circles (Spiral Inductor Design) recourse will definitely need to be made to an American textbook.

On the other hand, the selection of HP semiconductors offered is an up-to-date method of reference in a databook, which every interested person can use immediately. In addition the semiconductor S parameter data provided in Touchstone format (one complete floppy full) can be used in CAD programs. To use them in the program Puff a conversion utility is needed, which Klaus-Juergen Schoepf DB3TB has made available.

LITERATURE

(1) Robert E. Lentz, DL3WR: Puff - A CAD program for microwave stripline circuits VHF COMMUNICATIONS 23 (1991), pp 66-68.

Follow-up to the article 'PUFF - a CAD Program for Microwave Stripline Circuits'

The editor and publisher would like to thank readers for the many letters they received advising other CAD software programs. As soon as these come down to an amateur price level, we will mention them.

PUFF Software Availabilty Update

We have now (end August 1991) placed a regular combined order for Puff. In addition to the original Puff diskette with handbook, the publisher can now offer:

- ◆ two 360k diskettes with operational examples of Puff and S parameters of Motorola semiconductors.

- ◆ a 1.2Mb diskette with data sheets, a selection list and S parameters (Touchstone format) of modern semiconductors from Siemens. Commercial CAD systems can use this data as it stands, for Puff users the publisher will copy the transformation utility by DB3TB. The data is compressed but comprehensive information is given on the disk (in English and German) to help you.

- ◆ two 3.5'' diskettes with S and noise parameters of Philips RF transistors (thanks to OMs Lampe and Lehnerdt at Philips Components, Hamburg).

Once again the parameters are in Touchstone format and Puff users will need DB3TB's utility (on the Siemens disk). Philips disk 1 contains comprehensive instructions (in English), selection tables and data on transistors with leads. Disk 2 has data on SMD transistors. For each type between 5 and 12 operational points are noted.

Editor, VHF Communications,
Mike J. Wooding G6IQM

Detlef Burchard, Dipl.-Ing., Box 14426, Nairobi, Kenya

Basics of Rectifying small AC Voltages with Semiconductor Diodes

The crystal detector discovered by Braun and Brandes at the beginning of this century is the oldest RF rectifier known. Its operation can be calculated by Schottky's theory of diodes (3).

The measurement of small AC voltages plays a major role in communications technology. Several authors in VHF COMMUNICATIONS have in fact concerned themselves with the problematics of the subject, among them Behrens (1), Kokot and Schwarzenau (2), Schuerings (4), Tiefenthaler and Roessle (5), Vieland (6).

It remains now to set out the ground rules, so that we can learn why one diode works well and another does not. If we understand the physics, then we can improve this or that circuitry.

1. THE THEORY

The formula for the characteristic curve of the diode given back in 1939 by Schottky (3) is still valid today for all semiconductor diodes:

$$\frac{I}{I_S} = e^{U/U_T} - 1; U_T = \frac{k \cdot T}{e} \qquad (1)$$

U and I represent here the voltage and current of the diode, I_S a constant dependent upon material and surface area (equivalent to the theoretical barrier current) and U_T another constant in which are comprised Boltzmann's constant k, absolute temperature T and elementary loading e. This semi-logarithmic function is seen in Fig.1. The track in the region of the zero points of the co-ordinates is not very clear and has been redrawn with linear ordinates in Fig.2a. Fig.2b shows a section of the curve much higher up, once more with linear ordinates. The zero point

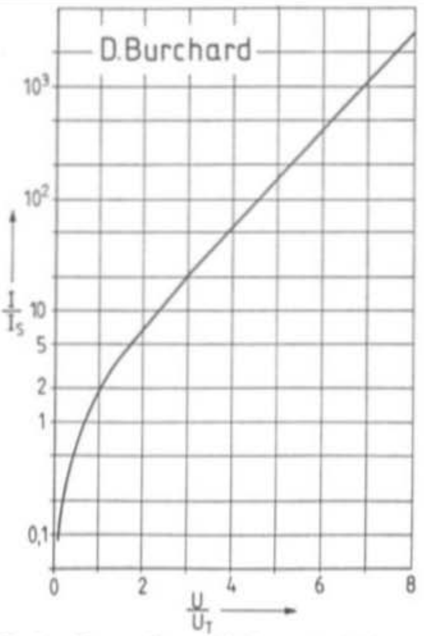


Fig.1: Generally valid characteristic curve of the diode according to Schottky's Theory

region is interesting for rectification without forward bias, the other region for rectification with forward bias.

Curve sections a and b have the same coverage with the scale chosen. There is no sign of any dogleg or threshold, although these things can stubbornly present themselves. Both sections of the curve are equally suitable for rectification and produce the same rectified DC voltage. To demonstrate this, some maths are necessary.

We think of a rectifier arrangement like Fig.3. AC is fed to the diode via a capacitor C, while the (short circuit) rectified current produced is led via coil L to the current meter. At the diode we have the AC voltage

$$U = \hat{U} \sin \Omega t,$$

in the diode is flowing the current

$$\frac{I}{I_S} = e^{\hat{U} \sin \Omega t / U_T} - 1$$

According to Taylor, the e-function for any exponents can be developed as a series

$$e^x - 1 = \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + ...$$

For small values of x we can already cut off after the second element (corresponding to reaching closer to a parabola, but should not be interpreted as if it really were a parabola). Then we get

$$\frac{I}{I_S} = \frac{\hat{U}}{U_T} \sin \Omega t + \frac{1}{2} \frac{\hat{U}^2}{U_T^2} \sin^2 \Omega t$$

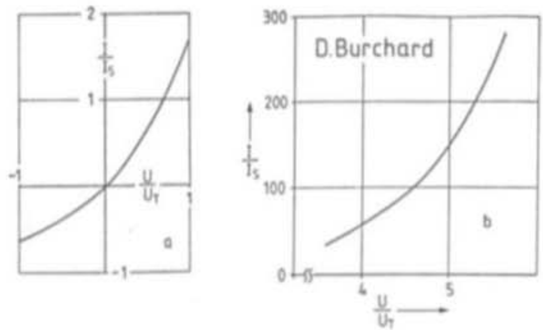


Fig.2: a) Diode characteristic curve in the zero-point region
b) and where U/U_T =2 * In 10

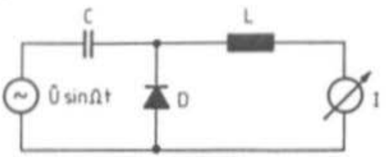


Fig.3 Calculated model of the Rectifier

and following the solution of the second term according to the rules of trigonometry

$$\frac{I}{I_S} = \frac{\hat{U}}{U_T}\sin\Omega t + \frac{1}{4}\frac{\hat{U}^2}{U_T^2} - \frac{1}{4}\frac{\hat{U}^2}{U_T^2}\cos 2\Omega t \quad (2)$$

The first and third term are alternating currents of the generator frequency and double the frequency. They flow to and fro via C. If we reckon on more elements of the series development, then amplitudes of the higher harmonic currents are produced. The second term of equation (2) is the desired rectified current through L and the current meter I, and it increases with $\hat{U}^2$. Thus the known quadratic rectifier effect is a natural consequence of the characteristic curve, and, since U_T is a natural constant, and equal and unalterable for all diodes independent of the operational point (so long as it is selected within the exponential region). Since the left side of equation (2) is still normalised, the actually measured current is proportional to I_S, thus independent of the material and surface area of a diode.

To get the (no load) rectified voltage we must calculate the diode resistance. It is the reciprocal of the gradient at the zero point, thus generally

$$R = \frac{1}{S} = \frac{dU}{dI} = \frac{U_T}{I_S} \cdot \frac{1}{e^{U/U_T}}$$

and with U=0

$$R_0 = \frac{U_T}{I_S} \quad (3)$$

The rectified voltage is then

$$U_R = R_0 \cdot I_R = \frac{1}{4}\frac{\hat{U}^2}{U_T} \quad (4)$$

independent of I_S, that is of the material and surface area of the diode.

With forward bias we get a quite similar result. In all the formulae we write I_V instead of I_S, giving the composite result

$$I_{RV} = I_V \cdot \frac{1}{4} \cdot \frac{\hat{U}^2}{U_T^2};$$

$$R_V = \frac{U_T}{I_V};$$

$$U_{RV} = \frac{1}{4} \cdot \frac{\hat{U}^2}{U_T}.$$

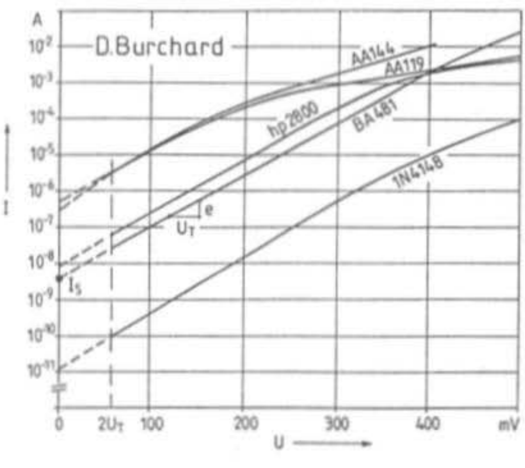


Fig.4: Measured characteristic curve of some commonly available rectifiers

A diode with little I_S produces little I_R to start. Supplied with matching forward bias, I_R then grows proportionately. At the same time the temperature-independence of I_S disappears (a few per cent per degree).

An amazing fact emerges, that rectified voltage is the same in all diodes and independent of forward bias. Quod erat demonstrandum!

2. THE PRACTICE

Commercially available diodes have characteristic curves as in Fig.4. Even with those diodes which are exclusively for rectifier applications, the manufacturers give no data for I_S and U_T.

If the characteristic curve has been recorded, which for small currents is not easy, then these constants can easily be read off. Extending the straight-line portion to the ordinates gives us I_S. U_T is the voltage change in the straight-line portion for a current variation around e=2.718. On the curve for the BA481 these values have been noted.

The theoretical value of U_T is 26mV at room temperature. From this we arrive directly at the temperature coefficient of 87uV per degree. In practice, however, values of U_T up to 50mV appear. Scientists have therefore discovered a "crumple factor" m, to be inserted ahead of U_T in the formulae. It has values from 1 to 2 and thus explains differences in the rectified voltage from 1:2 between different types of diodes. To interpret it as an increased temperature (e.g. "hot carrier diode") is, however, a mistake. Even Schottky diodes are close to 1 in m. A significant reduction of U_T (freezing spray) will increase rectified voltage in practice. I am not aware of any apparatus which exploits this effect, however.

In recording the characteristic curve no values below $2.U_T$ are necessary. As already seen in Fig.1 the curve bends steeply below there. Although it is just this region which is used for rectification without forward bias, we do not need to record it to determine I_S and U_T. We can note, however, that $2 * U_T$ is the boundary between quadratic and linear rectification (small and large signal operation). Disregarding that some curves in Fig.4 get flatter with higher currents, which again does not interest us for zero point operation, it is remarkable how scattered the field of I_S is. Varying with I_S are the rectified current, the diode resistance, and also the increase on AC power and decrease in DC power. The latter is much more important than the rectification constant K_R in microamps per microwatt sometimes offered; its definition is given here for the sake of completeness:

$$K_R = \frac{\frac{d^2I}{dU^2}}{\frac{dI}{dU}} = \frac{I_R}{N_{in}} = \frac{1}{U_T}$$

The input power is independent of the load resistance

$$N_{in} = \frac{\hat{U}^2}{2} \cdot \frac{1}{R_0} = \frac{\hat{U}^2}{2} \cdot \frac{I_S}{U_T}, \qquad (5)$$

while output power when matched to R_0 is at its greatest and then is:

$$N_{out} = \frac{I_S}{64} \cdot \frac{\hat{U}^4}{U_T^3}. \qquad (6)$$

If R_0 is small, because I_S is large, then the output power is also large. An AA119 delivers $3 * 10^4$ fold output power more than a 1N4148. The latter can produce just as much when supplied with a forward bias of $3 * 10^{-7}$A. The conversion degree of operation is, on the other hand, not dependent on I_S. It is

$$\frac{N_{out}}{N_{in}} = \frac{1}{32} \cdot \frac{\hat{U}^2}{U_T^2}. \qquad (7)$$

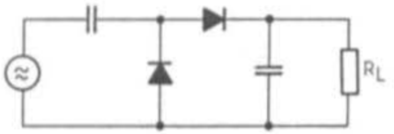


Fig.5 Doubler circuit

Forward biassing is totally unproblematic if it is just a case of recovering modulation, as in ref. 4.

If, however, the interest in the rectified voltage is in its absolute value (power measurement), then the simultaneous presence of forward bias at least of some concern. For compensation we need a (possibly expensive) diode of the same type with the same forward biassing current to arrive at the difference of the two diode voltages.

The problem is the same as in differential amplifiers, where base-emitter voltages of several hundred mV have to be compensated to a few microvolts too. With diodes on a crystal it would be easier and above all, more thermally stable. Otherwise one can hold the equalisation over some time perhaps only to 10 microvolts. To this rectified voltage belongs an input AC voltage of around 1mV amplitude, i.e. 0.7mV effective value (-50 dBm/50 ohms), which should be seen as the boundary of detection (not the threshold!).

If one can detect even smaller voltage variations, then one can measure even smaller AC voltages. The boundary of detection thus depends more on the sensitivity (noise figure) of the following amplifier. By reducing the bandwidth and noise matching to the source resistance R_0 or R_V, it can theoretically be made as small as desired.

Schottky diodes can be produced in a large I_S region, viz. from 10^{-3} to 10^{-11}A. Taking an example, with $I_S = 0.6 * 10^{-3}$, R_0 is 50 ohms. This diode in a measurement probe could record the complete AC power without reflection. With such a low R_0 the noise will be low too (0.1 microvolt in 10kHz bandwidth), so low drifting chopper amplifiers with less than 0.1 microvolt offset are feasible. A boundary of detection of 0.07mV[eff] (-70dBm/50 ohms) would result. This noteworthy diode would, however, probably have such a large surface area (capacity) that it would not be suitable for higher frequencies. But it would work in the short wave region!

Modern diode power meters achieve the indicated boundary of detection using diodes with significantly lower I_S through the use of slow chopper amplifiers and averaging for several seconds. If you intend sweeping or measuring short AC impulses, have nothing to do with these. However, a broadband amplifier can easily reduce the limit of detection sufficiently.

Schottky diodes are currently offered with low, medium or high barriers, which of course immediately suggest they have a built-in threshold. As I hope I have substantiated, such a classification is nonsense. What they really mean is high, medium or low I_S, and a figure with the unit of measurement would be better! Schottky diodes with a high I_S (what the sales "engineers" call low barrier) are currently the best for rectifying small AC signals. To label them as a substitute for germanium diodes and then sell then at 200 times the price can be justified at any event for the microwave region, where germanium diodes are no longer usable.

For the radio amateur the germanium diode remains the best choice for the time being and one must live with I_S values of between 10^{-6} and 10^{-7} A.

Because of the quadratic relationship of equation (4) the rectified voltage is in a strong

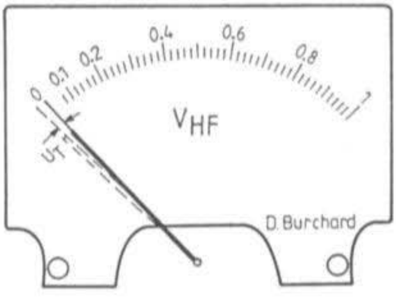


Fig.6: Scale of an RF Voltmeter with linear display

sense independent of the curve shape of the AC voltage and a measure for the power. If the voltage is of interest, then U_R must be calculated by extracting the root. The quadratic region ends at 2 * U_T (Fig1), which corresponds to 35 to 70mV [eff] (-16 to -10dBm/50 ohms).

3. LARGE SIGNAL OPERATION

The measurement range of such a rectifier covers 40 to 60dB. To extend this without a preamplifier is possible only with higher voltages. The diode now works as a peak rectifier, its input resistance is dependent on the load resistance and the shape of the curve plays a role. The last dependence can be improved quite significantly if two-way rectification takes place as in Fig.5. In small signal operation as well it provides double the rectified voltage, has half the input resistance and double the output resistance compared with the circuit in Fig.3.

In large signal operation, the input resistance is one eighth of the load resistance. If the rectifier is to represent a voltage-independent input resistance, then its load should be selected as 4 * R_0 (the value of a diode), for example 240kohms if using two AA119, which each have 60kohms. With this load the rectified voltage drops by a third in small signal operation. One can use this criterion to select an exactly matching load without knowing the value of R_0.

Knowledge of the relationships enables us to develop an RF voltmeter with a linear scale. We preset the zero point at U_T and provide a linear division only above 2 * U_T (Fig.6). Such a device with 1V full-scale deflection has no rectification error larger than 0.5 per cent of full-scale deflection. The technique was common 30 or 40 years ago with universal valve voltmeters and of course can be used today. Thermionic diodes follow the initial current law, which is also an e-function. In this case U_T lies at 120mV because of the cathode temperature of 1200 degrees Kelvin. Hence they have a boundary of detection around four times higher than semiconductor diodes. They always operate with forward bias, which is produced by the initial current.

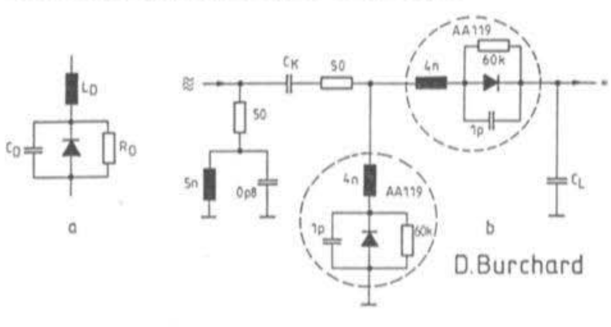


Fig.7:
a) Equivalent circuit of a diode at high frequencies and:
b) Broadband compensation for constant Z=50 ohms together with optimum flat frequency response (values for

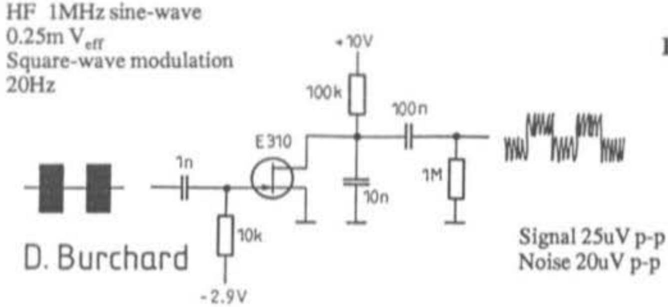


Fig.8: FET Rectifier with low detection limit

4. RF USAGE

At higher frequencies of AC voltage the inductance of lead wires and diffusion capacity of the diode become noticeable. Fig.7a shows the equivalent circuit. C_D and L_D produce resonance with excessive voltage if the generator voltage is sufficiently small; typically for a AA119 for example this is at 2.5GHz. In large signal operation, moreover, Cd varies because an appreciable barrier voltage arises. A preceding resistance can now be selected to achieve as flat a frequency response as possible at a given generator resistance. This is generally determined faster experimentally than theoretically.

If the rectifier is in a 50-ohm measuring probe, then it is possible to achieve a flatter frequency response as well as reflection factor. We need to dimension a diplexer according to Fig.7b which is proportioned as a branching filter with Z=50 ohms. Proven values for AA119 two-way circuits are noted.

5. TRANSISTORS AS RECTIFIERS

Rectifiers which follow the same law will exhibit the same dependency of one value on another. Take as an example the relationship $I_C = f(U_{BE})$ in a bipolar transistor or $I_D = f(U_{GS})$ in a FET exponentially in defined current regions. Both transistors are available as dual versions, which makes compensation of the forward bias current particularly simple. Also U_T is entirely similar to diodes. The boundary of detection and the quadratic region also turn out similar.

An experimental circuit as in Fig.8 produced right away a boundary of detection of 0.25mV.

6. LITERATURE

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Wilhelm Schüerings, DK4TJ and Wolfgang Schneider, DJ8ES

Universal Transverter Concept for 28, 50 and 144MHz

An edited version of the presentation at the 35th VHF Conference at Weinheim, 1990.

The transverter described, thanks to its universal concept, creates new dimensions for the 10, 6 and 2 metre bands. The universal flexibility applies not only to the frequencies which can be achieved but also to the choice of intermediate frequency.

Following good results with modules using 50-ohm techniques a linear transverter was also made in this fashion. It comprised a receive converter, transmit mixer and oscillator all derived from standard 50-ohm circuits. Considerable emphasis was placed on good

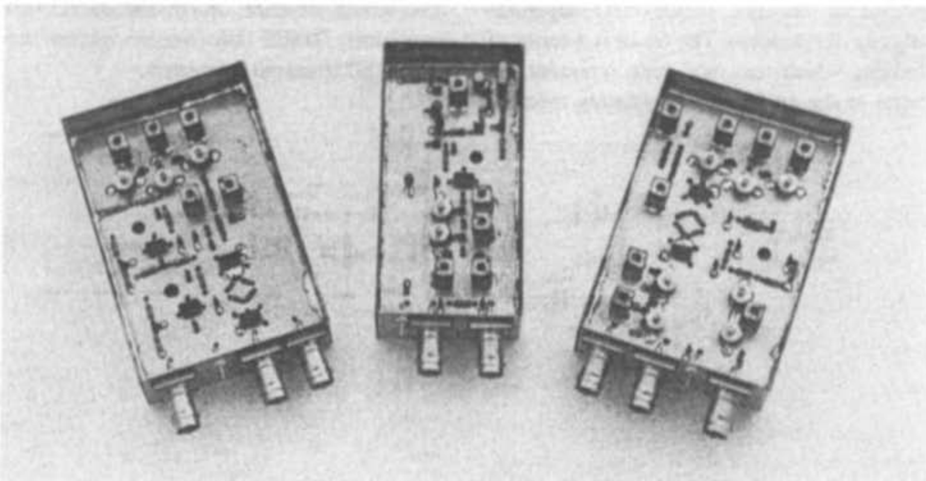


Fig.1: Transverters of the three patterns

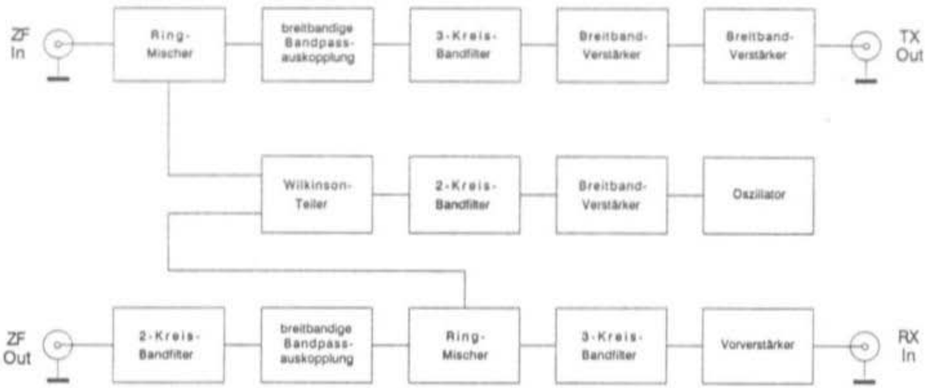


Fig.2: Block Diagram of the Universal Transverter

technical data and reliable operating characteristics, together with simple construction and guaranteed reproducibility. A further plus point for the 50-ohm techniques employed is that a variety of frequency bands can be accommodated merely by changing those components which are frequency-critical.

At first sight the circuits might appear somewhat demanding, but the results justify the effort. Apart from the crystal and Neosid coils, all the components should be already available in the average shack and minor component changes should not jeopardise integrity of operation. The result is a series of modules which may not quite represent the "state of the art" but will certainly measure up to commercial productions in their technical specification.

This article describes the circuitry and construction of a 28 to 50 MHz transverter prototype (Fig.1) and also details the results achieved. The block circuit diagram (Fig.2) gives an overview of the individual modules such as oscillator, transmit mixer and receive mixer. The functional elements such as ring mixer, filters and dividers are also visible.

As Fig.1 shows, the transverter is divided into three screen modules, designated DJ8ES 005 (oscillator), DJ8ES 006 (receive mixer) and DJ8ES 007 (transmit converter).

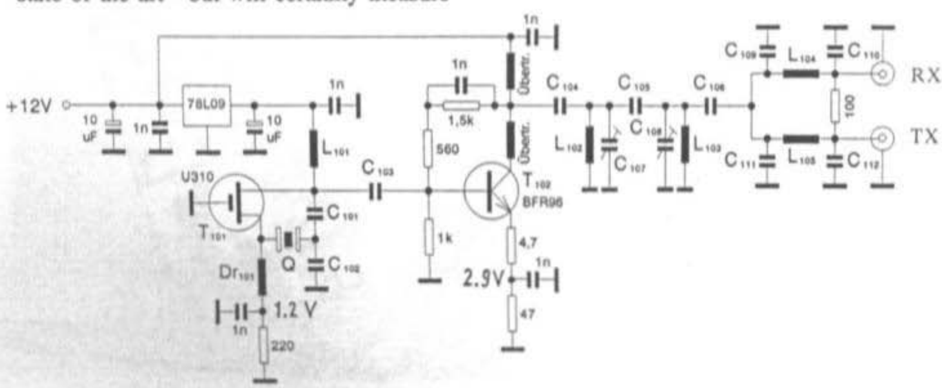


Fig.3: Circuit of the Universal Transverter

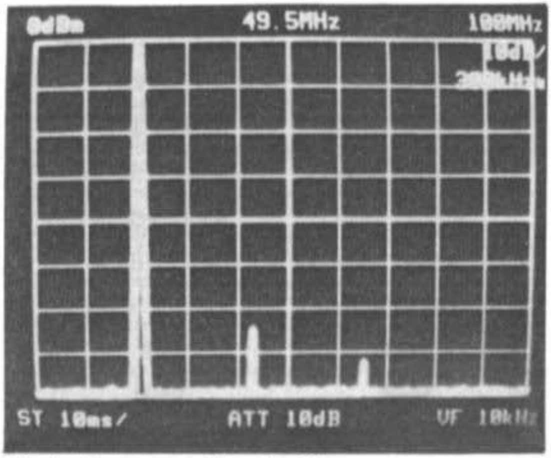


Fig.4: Spectrum of the Oscillator

1. THE OSCILLATOR MODULE

The oscillator module DJ8ES 005 is comprised of the actual local oscillator (LO), a wideband amplifier with two-pole filter following and the Wilkinson divider necessary for splitting the output.

1.1 Circuit description

Fig.3 shows the complete circuit. The oscillator is a trusted circuit using a U310 (T101), laid out for the overtone. In the sample illustrated (for a 28/50MHz transverter) the oscillator operates at 22MHz.

Following the LO is a loosely coupled wideband amplifier, built in 50-ohm techniques; it raises the oscillator signal to around 40mW. A good 50-ohm match is achieved by push-pull coupling between collector to base and emitter to base. This reduces the total amplification achievable but increases the bandwidth significantly.

The two-pole filter (Butterworth filter) following ensures a "clean" oscillator signal. Harmonic suppression of better than 60dB is achieved.

For splitting the LO signal for the transmit and receive mixers a Wilkinson divider (1) is employed. This 3dB coupler halves the oscillator signal, providing 20mW (+13dBm) on each output.

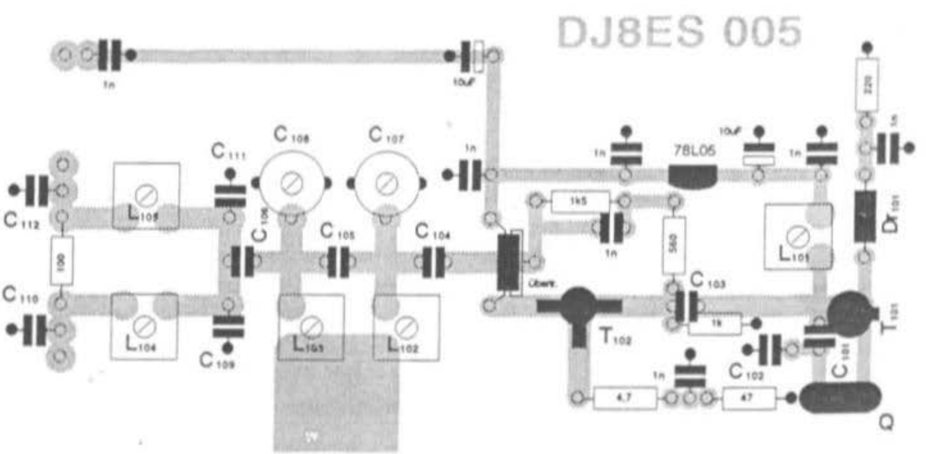


Fig.5: Component layout for the board DJ8ES 005

Umsetzung	28 MHz / 50 MHz	50 MHz / 144 MHz	28 MHz / 144 MHz
Quarz	22 MHz	94 MHz	116 MHz
L101	BV5048 ge/gr	BV5061 br/bl	BV5061 br/bl
L102	BV5036 or/bl	BV5061 br/bl	BV5061 br/bl
L103	BV5036 or/bl	BV5061 br/bl	BV5061 br/bl
L104	BV5036 or/bl	BV5061 br/bl	BV5061 br/bl
L105	BV5036 or/bl	BV5061 br/bl	BV5061 br/bl
C101	56pF	18pF	12pF
C102	330pF	82pF	82pF
C103	4p7	2p7	2p7
C104	27pF	8p2	5p6
C105	4p7	1p8	1p0
C106	27pF	8p2	5p6
C107	90pF (rot)	40pF (grau)	40pF (grau)
C108	90pF (rot)	40pF (grau)	40pF (grau)
C109	100pF	27pF	22pF
C110	100pF	27pF	22pF
C111	100pF	27pF	22pF
C112	100pF	27pF	22pF
Dr101	10µH	1µH	1µH

Table 1: Frequency-dependent items in oscillator DJ8ES 005 (see Table 2 for colour code translations)

1.2 Construction details

The PCB is made from double sided epoxide material 1.5mm thick and has the dimensions 53.5mm x 108mm; in this way it fits in a commercial tinplate case (55.5 x 111 x 30). After the PCB has been trimmed it can be drilled. The BFR96 (T102) lies within the board and a suitable hole should be drilled for it.

Following this the isolation holes for resistors, capacitors, crystal, coil formers, etc can be made on the groundplane (unetched) side of the PCB using a 2.5mm drill to mill away sufficient of the copper surface. Once done, the PCB can be sprayed with flux varnish.

Component assembly of the PCB (Fig.5) can proceed once the tinplate frame has been soldered on. The BNC connectors should be fitted centrally, then the PCB offered up so that its etched side very nearly touches against the teflon collars of the BNC sockets.

Special care should be devoted to winding and connecting the transformers. In the wideband

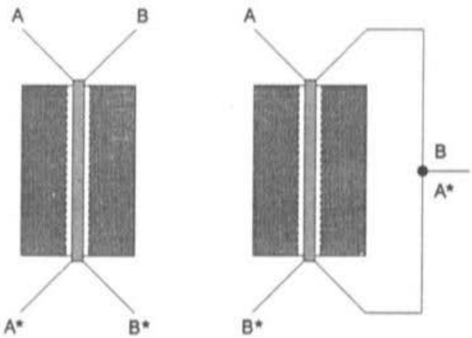


Fig.6: **Transformer connection scheme**

amplifier stage the transformer comprises a bifilar coil (six turns on a ferrite bead). The bifilar coil is best wound as follows: take two pieces of 0.2mm diameter varnished copper wire ("A" and "B") of equal length and carefully plait them together with a hand drill. The appropriate number of turns of this double wire is threaded onto the core. Then the end of coil A is connected to the start of coil B (Fig.6).

For the wideband amplifier ferrite beads represent a simple and cheap opportunity. But ring and double hole cores are equally well suited, e.g. Philips 4C6, Siemens K1 and Siemens U17, and in this case 0.3mm wire can also be used.

1.2.1 Components

T101:	U310 (Silconix)
T102:	BFR96 (Valvo)
C101-106:	ceramic disc, 2.5mm spacing (see Table 1)
C107, 108:	foil trimmers 10mm dia. (see Table 1)
C109-112:	ceramic disc, 2.5mm spacing (see Table 1)
L101-105:	Neosid coil (see Table 1)
Dr101:	axial choke (see Table 1)
Transformers:	see text

2 x tantalum bead electrolytics 10uF/16V
1 x 9V regulator 78L09
1 x crystal HC-18U or HC-25U (Table 1)
1 x Teflon feed-through
2 x BNC flange connectors UG-290A/U
1 x tinplate housing 55 x 111 x 30mm

Resistors type 0207, formed to 10mm spacing

1	4R7
1	47R
1	100R
1	220R
1	560R
1	1K
1	1K5

Ceramic disc capacitors, 2.5mm lead spacing

6	1nF

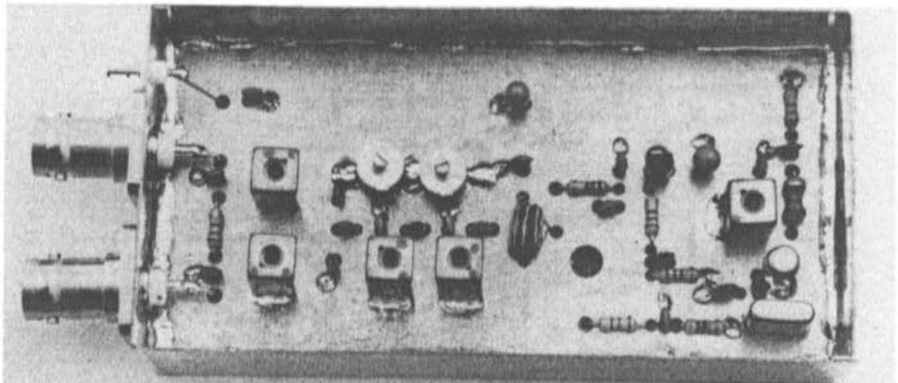


Fig.7: A completed oscillator module

1.3 Alignment

The following test equipment is required:

- ◆ Multimeter
- ◆ Power meter
- ◆ Frequency Counter.

To bring the oscillator module into service the power supply should be connected: the current drawn should be around 50mA at 12V. The supply voltage is not critical to the wideband amplifier and the regulator ensures a fixed 9V, so any voltage between 11 and 14V can be used.

The oscillator can be brought onto frequency with the aid of coil L101. Next the two-pole filter must be tuned for maximum output efficiency, which can be done without problems by connecting a power meter to the TX or RX output.

Note that the unused output must be terminated in 50 ohms.

The module is now ready for use (Fig.7).

2. THE RECEIVE MIXER

2.1 Circuit description

Figure 8 shows the circuit which has just one transistor and a ring mixer.

The PI-filter transforms the antenna impedance of 50 ohms to the impedance gate of the BF981 (T201). At the output of the preamplifier the transistor impedance is matched to the following three-pole filter with C203. Next come the home-made ring mixer. a wideband matching stage and a two-pole filter for the IF.

This matching may appear burdensome at first sight but its importance will be revealed in the next section (3. The Transmit Mixer) and supported by test measurement results.

Crucial to its quality is the module's performance in the face of strong signals, and the 3rd order intercept point (IP3) needs to be determined. With two input signals each of -25dBm a figure of -13dBm per single tone is

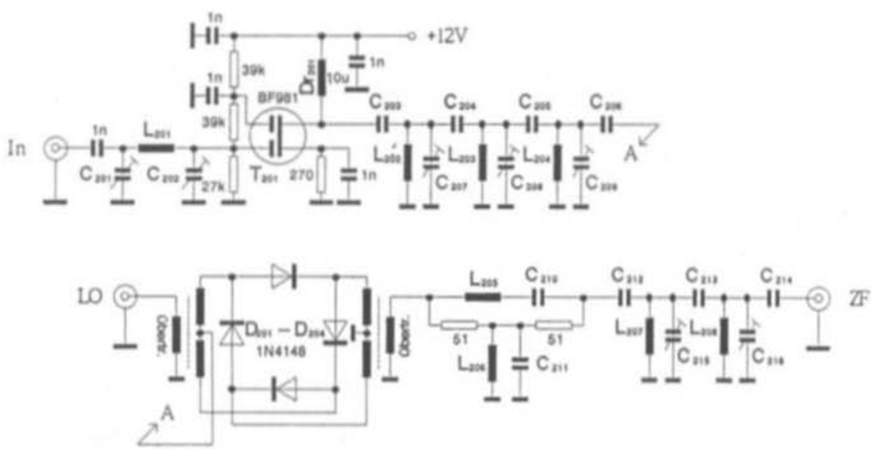


Fig.8: Circuit of the Receive Mixer DJ8ES 006

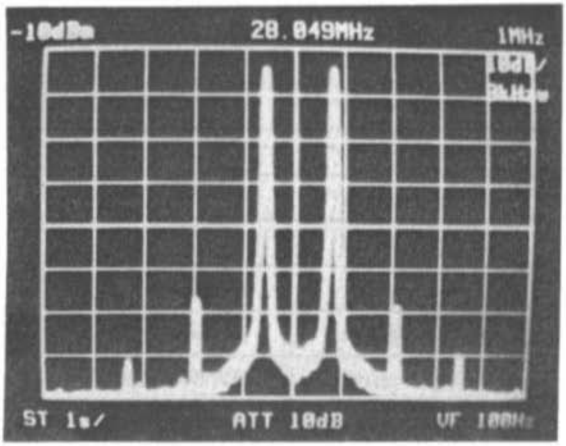


Fig.9: Spectrum for determining IP3

measured at the module's output. This represents through amplification of 12dB. The 3rd order intermodulation products (IM3) are 54dB below the single tone, giving an IP3 of +2dBm (Fig.9).

2.2 Construction details

The PCB is made from double sided epoxide material 1.5mm thick and has the dimensions 72mm x 108mm; in this way it fits in a commercial tinplate case (74 x 111 x 30).

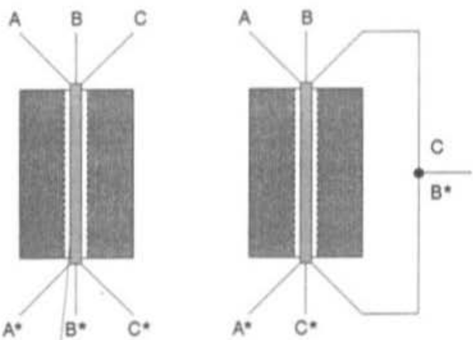


Fig.10: Trifilar Transformer connection scheme

Preparation and subsequent component assembly follow the same process as described for the oscillator module (see section 1.2).

Two transformers are employed in the ring mixer; they are formed of trifilar windings with six turns on 5mm ferrite bead.

Three lengths of varnished copper wire of 0.2mm diameter are used and the same instructions given in section 1.2 are valid (Fig.10).

2.2.1 Components

T201:	BF981 or similar DG-MOSFET
C201, 202:	Foil trimmer, 10mm spacing (see Table 2)
C207-209:	ditto
C215, 216:	ditto
C203-206:	ceramic disc, 2.5mm spacing (see Table 2)
C210-214:	ditto
L201-208:	Neosid coil (see Table 2)
Dr201:	Neosid choke 10uH axial
Transformer:	see text
D201-204:	1N4148 diodes or special mixer diodes
1	Teflon feedthrough
3	BNC flange connectors UG-290A/U
1	tinplate housing, 74 x 11 x 30

Resistors 0207, formed to 10mm spacing:

2	51R
1	270R
1	27K
2	39K

Ceramic disc capacitor, 2.5mm lead spacing:

5	1nF.

Frequenz	28 MHz	50 MHz	144 MHz
L201	BV5048 ge/gr	BV5036 or/bl *	BV5049 ge/ws
L202	BV5036 or/bl	BV5049 ge/ws *	BV5061 br/bl
L203	BV5036 or/bl	BV5049 ge/ws *	BV5061 br/bl
L204	BV5036 or/bl	BV5049 ge/ws *	BV5061 br/bl
L205	BV5049 ge/ws *	BV5049 ge/ws	BV5034 --/--
L206	BV5049 ge/ws *	BV5061 br/bl	BV5034 --/--
L207	BV5049 ge/ws *	BV5049 ge/ws	BV5061 br/bl
L208	BV5049 ge/ws *	BV5049 ge/ws	BV5061 br/bl
C201	70pF (gelb)	70pF (gelb) *	40pF (grau)
C202	40pF (grau)	40pF (grau) *	40pF (grau)
C203	8p2	4p7 *	1p0
C204	3p3	1p5 *	0p5
C205	3p3	1p5 *	0p5
C206	22pF	12pF *	3p9
C207	70pF (gelb)	40pF (grau) *	40pF (grau)
C208	70pF (gelb)	40pF (grau) *	40pF (grau)
C209	70pF (gelb)	40pF (grau) *	40pF (grau)
C210	120pF *	39pF	22pF
C211	120pF *	100pF	22pF
C212	22pF *	12pF	3p3
C213	5p6 *	2p2	0p5
C214	22pF *	12pF	3p3
C215	90pF (rot) *	40pF (grau)	40pF (grau)
C216	90pF (rot) *	40pF (grau)	40pF (grau)

Table 2: **Frequency dependent items in receive mixer DJ8ES 006.**
Since a total of six transverter combinations are possible (28 to 30, 28 to 144, 50 to 28, 50 to 144, 144 to 50 and 144 to 28) one module must be made according to the values in each appropiate column.

***Example: receive mixer 50MHz to 28MHz**

(ge = yellow, gr = green, or = orange, bl = blue, grau = grey, rot = red, br = brown and ws = white)

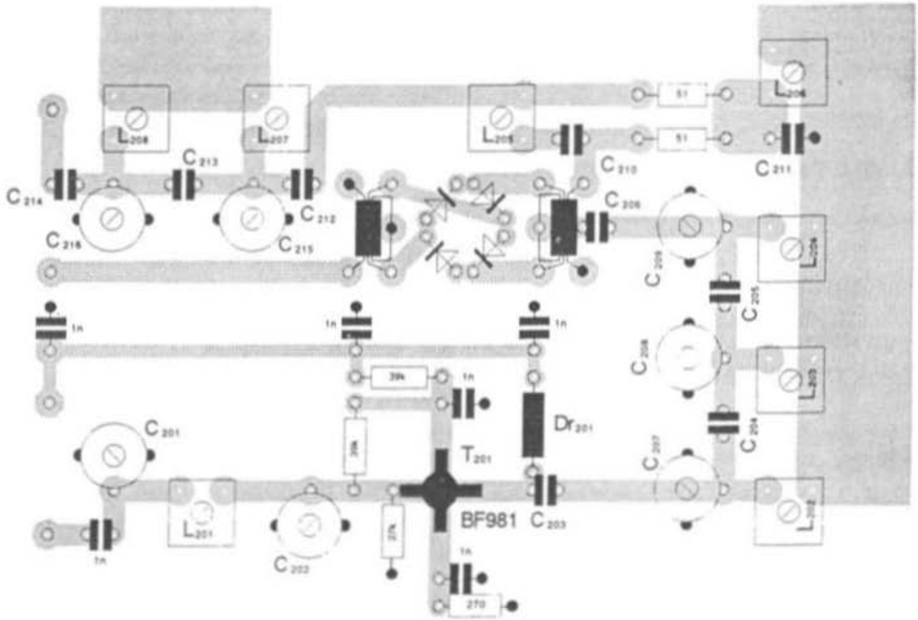


Fig.11: Component Layout of board DJ8ES 006

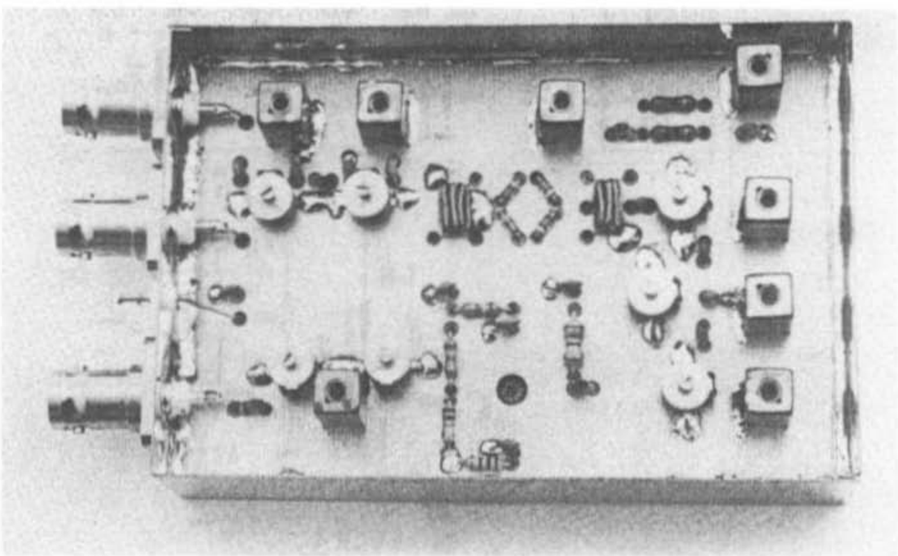


Fig.12: Completed Receive Mixer DJ8ES 006

Fig.11 shows the component layout of the receive mixer PCB, Fig.12 shows a test sample of this module.

2.3 Alignment

The following test gear is required:

◆ Multimeter

◆ Test Generator, or received off-air signal, fed to the receiver via the antenna.

To put the receive mixer in service connect the power supply (+12V) and the oscillator module. The current drawn is around 12mA. Just like the oscillator, this module is suited to all "portable" and "mobile" voltages.

First the two Butterworth filters should be aligned, using a signal from the test generator or an off-air signal. Alternatively, on account of the fact that there are no active elements in the mixer, a transmit signal can be fed into the IF connector. Having connected a power meter, C203 can be adjusted to align the filter. Finally line up the PI-filter in the receive input for best signal-to-noise performance.

3. THE TRANSMIT MIXER

3.1 Circuit description

The transmit mixer (Fig.13) is formed of a ring mixer, wideband matching stage, three-pole filter and two-stage wideband amplifier. Four 1N4148 diodes are used in the ring mixer, with trifilar transformers for coupling in and out.

The wanted frequency is led via a wideband bandpass connection to the three-pole filter, with a two-stage wideband amplifier to produce the desired output level.

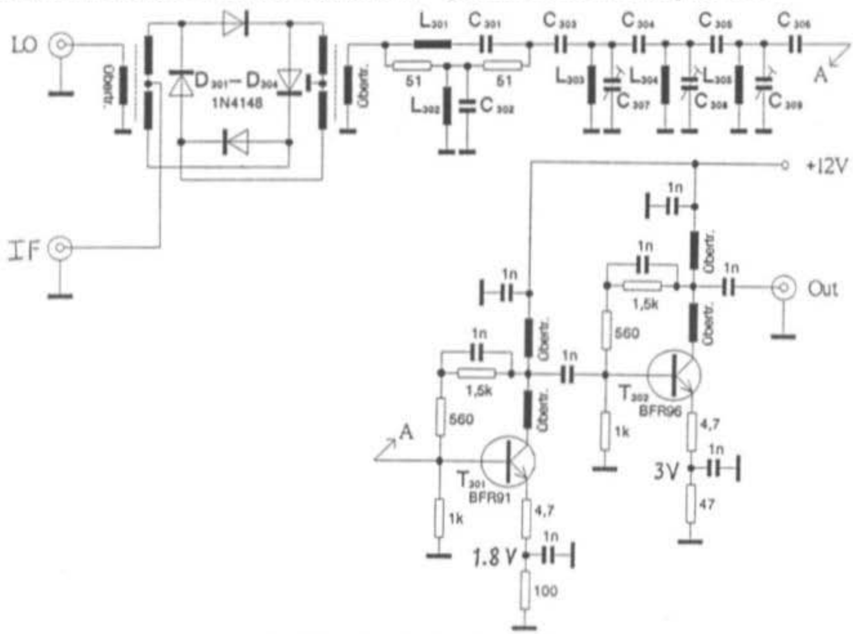


Fig.13: Circuit of the Transmit Mixer Module DJ8ES 007

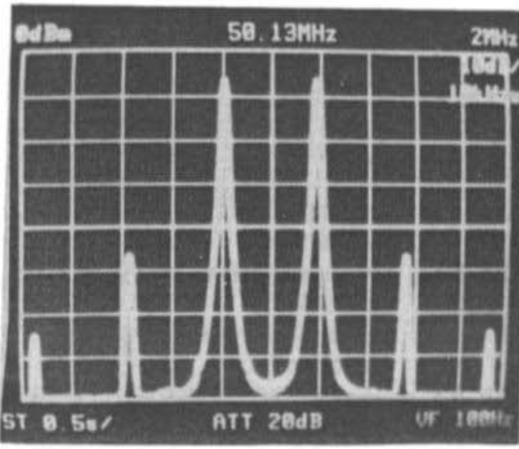


Fig.14: Output Spectrum when driven with a two-tone test signal

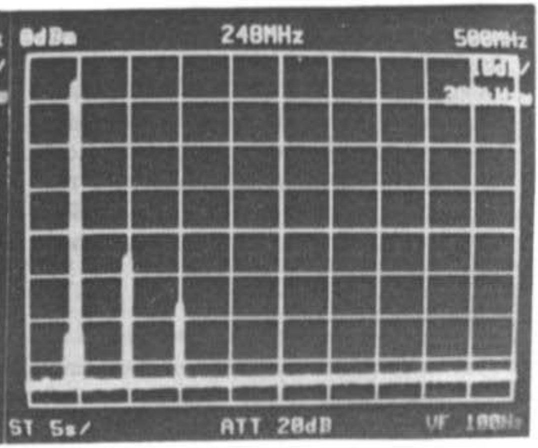


Fig.15: This photo shows the harmonic content more clearly

Frequenz	28 MHz	50 MHz	144 MHz
L301	BV5049 ge/ws	BV5049 ge/ws	BV5034 --/--
L302	BV5049 ge/ws	BV5061 br/bl	BV5034 --/--
L303	BV5036 or/bl	BV5049 ge/ws	BV5061 br/bl
L304	BV5036 or/bl	BV5049 ge/ws	BV5061 br/bl
L305	BV5036 or/bl	BV5049 ge/ws	BV5061 br/bl
C301	120pF	39pF	22pF
C302	120pF	100pF	22p
C303	22pF	12pF	3p9F
C304	3p3	1p5	0p5
C305	3p3	1p5	0p5
C306	22pF	12pF	3p9
C307	70pF (gelb)	40pF (grau)	40pF (grau)
C308	70pF (gelb)	40pF (grau)	40pF (grau)
C309	70pF (gelb)	40pF (grau)	40pF (grau)

Table 3: Frequency dependent components for the Transmit Mixer DJ8ES 007 (see Table 2 for colour code translations and selection example)

A drive level of 100uW (two-tone signal each -13dBm) produces at the output of the transmit mixer 55mW (+18dBm) per single tone, that is +21dBm PEP. With these operating conditions the 3rd order intermodulation products (IM3) are reduced by 41dB and IM5 by 60dB (Fig.14). Although the circuit has no filter for harmonics, suppression is better than 40dB at the drive level stated (Fig.15).

In practical operation these modules can be used with power amplifiers of any kind. Harmonic filtering is then absolutely necessary and some appropriate suggestions can be found in reference (5).

3.2 Construction details

The PCB DJ8ES 007 is made from double sided epoxide material 1.5mm thick and has the dimensions 72 x 108mm; in this way it fits in a commercial tinplate case (74 x 111 x 30).

Apart from this, construction is on the same lines as described earlier. The stripline transistors T301 and T302 should be embedded in the PCB.

3.2.1 Components

T301:	BFR91 (Valvo)
T302:	BFR96 (Valvo)
C307-309:	foil trimmer, 10mm spacing (see Table 3)
C301-306:	ceramic disc. 2.5mm spacing (see Table 3)
L301-305:	Neosid coils (see Table 3)
D301-304:	1N4148 diodes or special mixer diodes

Transformers:	(see description sections 1,2)
1	Teflon feedthrough
3	BNC flange connectors UG-290A/U
1	tinplate housing 74 x 111 x 30

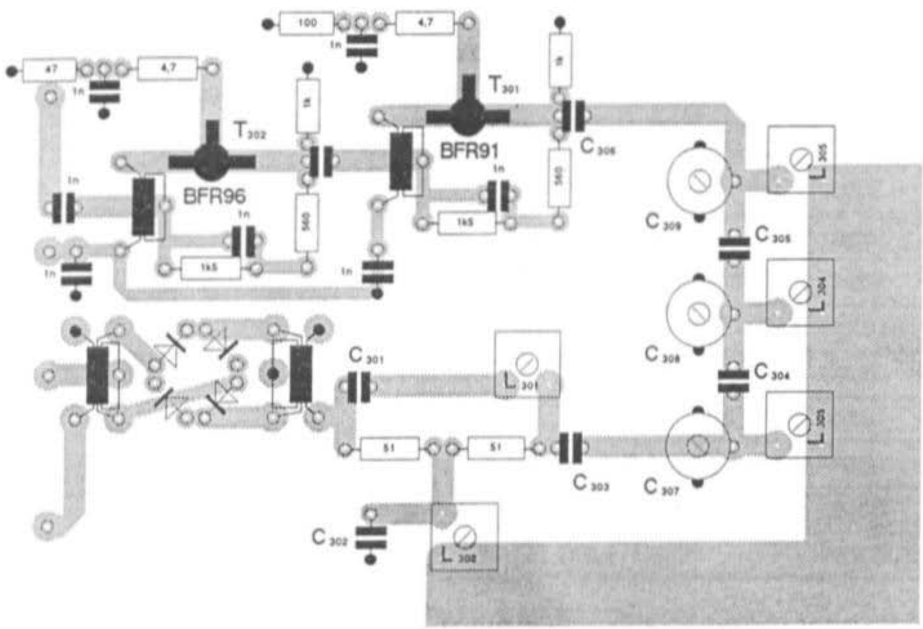


Fig.16: Component Layout for board DJ8ES 005

Resistors 0207, formed to 10mm spacing:

2	4R7
1	47R
1	100R
1	560R
12	1k
2	1k5

Ceramic disc capacitors, 2.5mm lead spacing:

7	1nF

Fig.16 shows the component layout of the transmit mixer board DJ8ES 007, while a completed module can be seen in Fig.17.

3.3 Alignment

The following test gear is required:

- Multimeter
- Power Meter
- Frequency Counter.

After applying operating voltage (+12V, about 75mA) and connecting the oscillator module the transmit mixer can be put into service. All that need be done is to line up the three-pole filter for maximum output power. This can be done without difficulty by connecting the power meter to the TX output. With the 100uW input drive mentioned at the beginning around 50mW should be achieved at the output.

4. LITERATURE REFERENCES

(1) Jessop, G.R., G6JP: Wilkinson Dividers, VHF-UHF Manual, 4th edition, page 6.6. RSGB 1983.

(2) & (3) Wilhelm Schuerings, DK4TJ & Wolfgang Schneider, DJ8ES: Conference papers of the 32nd and 34th Weinheim VHF Conference..

(4) Wes Hayward, W7ZOI and Doug DeMaw, W1FB: Solid State Design for the Radio Amateur, ARRL 1977.

(5) ARRL Handbook 1987 Output Filtering, page 11.8. ARRL 1986.

(6) Wes Hayward, W7ZOI: Introduction to Radio Frequency Design, Prentice Hall 1982.

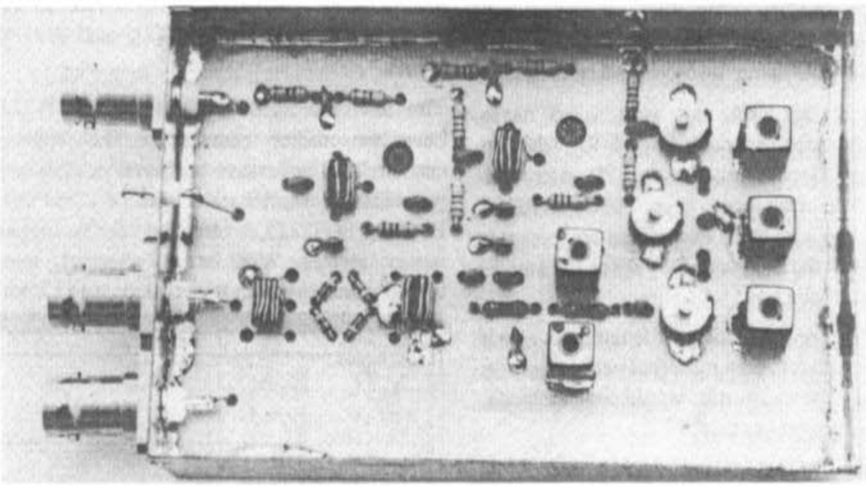


Fig.17: Transmit module DJ8ES ready for service

READERS' FORUM

SMD CRYSTALS FROM 4MHz TO 360MHz

The first European producer of surface-mounting crystals is Tele-Quarz, which is supplying these plastic-cased devices in a form suitable for infra-red or solder-bath soldering.

Crystals are available for the complete range 4MHz to 360MHz, and the XSO-4 and XSO-4L outlines have been proposed for a DIN standard.

FIRST EME QSO ON 10GHZ BETWEEN EUROPE AND USA

On the 2nd December 1990 the stations WA7CJO/KY7B (Phoenix, Arizona) and SM4DHN (Sweden) managed the first transatlantic QSO using the moon as a reflector.

In use at the USA end were a 4.8 metre parabolic reflector and 300 watts RF, while in Sweden a 6 metre antenna and 75 watts were used. The frequency was 10368.100GHz. Mode: CW and SSB. Participant and reporter SM6CKU thanks Dave KY7B for the travelling wave tube (!).

In passing, he thinks that for listening in a dish of 3m diameter and a modified very low-noise satellite TV converter would be adequate. Who is going to try this?

Info from Henk Ripet PA314 and Alois Pendl OE6AP. Thanks!

TRANSMITTING POWER TRANSISTORS FOR 900MHz

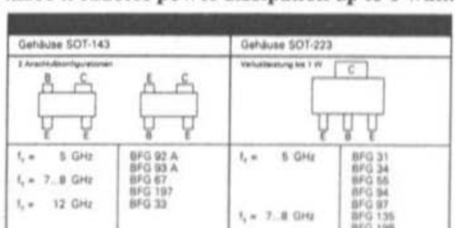
Timed to meet the development phase of the new digital cellular radio networks, Philips Components has released a family of transmit power transistors. Series BLV101xx enable an output power of 50 watts, while the BLV102xx offer 100 watts. Driver stages for use up to the oscillator level are naturally also V:F7 available.

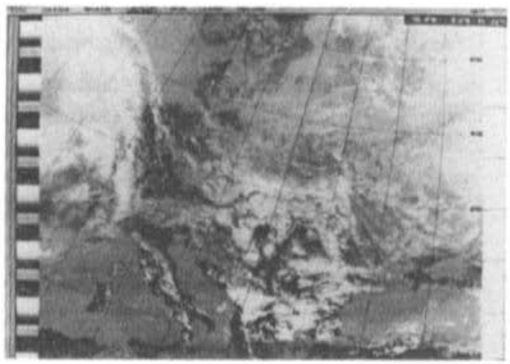
RF BROADBAND TRANSISTORS WITH TWIN EMITTER CONNECTIONS

At the upper frequency reaches parasitic capacity and inductance effects from device housings can have a significant influence on the performance of the devices, particularly on the amplification achievable.

Philips Components has started at the outset stage of developing SMD versions of transistors to make their cases better from an RF viewpoint than the old SOT-23 and SOT-89 styles.

The new case styles SOT-143 and SOT-223 have two emitter connections. The reduced emitter lead inductance achieved in this way provides an amplification gain of 2 to 3dB. Housing SOT-223 is intended for the higher power devices. With its low thermal resistance it enables power dissipation up to 1 watt.





MATERIAL PRICE LIST OF EQUIPMENT

described in VHF COMMUNICATIONS

DJ8ES	**FM ATV Receiver for the 23cm Band**		**Art.No.**	**Ed. 1/1991**
Converter				
PCB	DJ8ES 001	double-sided	6347	DM 22.00
Components	DJ8ES 001		6348	DM 179.00
Kit	DJ8ES 001	complete	6349	DM 194.00
Digital Frequency Indicator				
PCB	DJ8ES 002	double-sided	6350	DM 19.80
Components	DJ8ES 002		6351	DM 94.00
Kit	DJ8ES 002	complete	6352	DM 110.00
IF Amplifier				
PCB	DJ8ES 003	double-sided	6353	DM 15.00
Components	DJ8ES 003		6354	DM 105.00
Kit	DJ8ES 003	complete	6355	DM 115.00
Demodulator				
PCB	DJ8ES 004	double-sided	6356	DM 19.00
Components	DJ8ES 004		6357	DM 136.00
Kit	DJ8ES 004	complete	6362	DM 150.00

DL6MDA	**AD/DA Card**		**Art.No.**	**Ed. 2/1991**
PCB	DL6MDA 001	though-cont. single	6366	DM 38.00
Kit	DL6MDA 001	complete	6367	DM 110.00
Floppy disk with .EXE programme on 3.5" floppy			6368	DM 20.00

DBINV	**Digital Storage for the Spectrum Analyser**		**Art.No.**	**Ed. 3/1991**
PCB	DB1NV EXper.1	(ed...)	6475	DM 29.90
PCB	DB1NV EXper.11	(solder spots 2.3 x 1mm)	6476	DM 29.90
PCB	DB1NV 010		6477	DM 44.00
Special Components:				
	DB1NV 010, incl. programmed EPROM		6478	DM 276.00
	DB1NV 010, EPROM only		10080	DM 44.00

Post and packing minimum charges DM 6.50

The above items are all supplied by, and obtained from, UKW-Berichte in Germany.

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