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Radek Vaclavik
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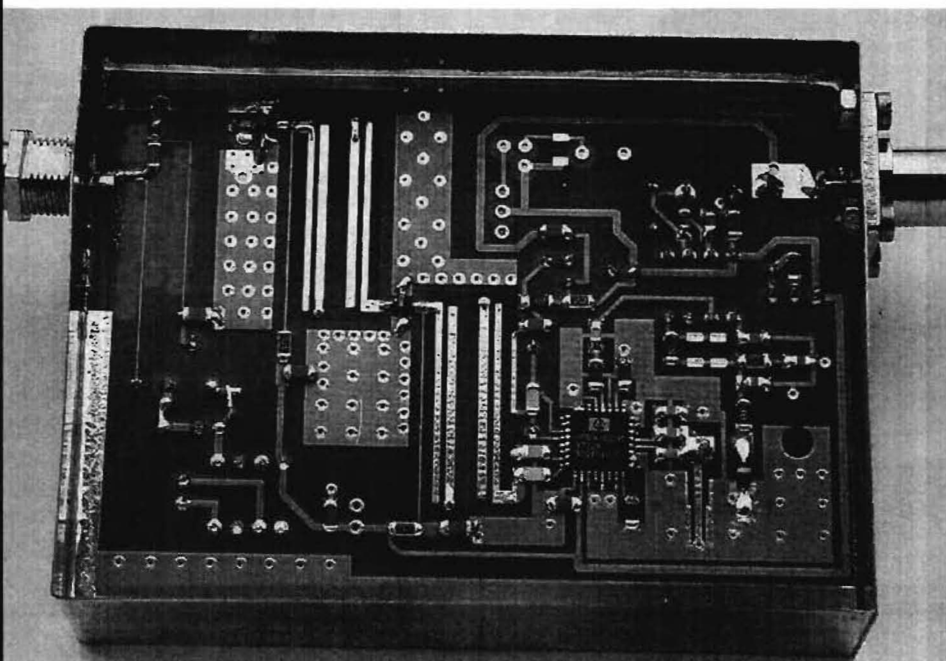

Simple Meteost Reception

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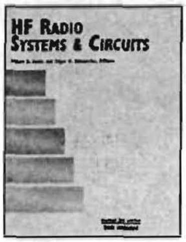

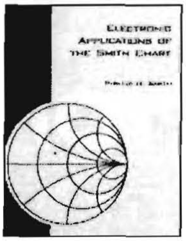

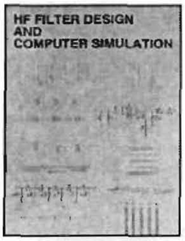

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Contents

For the last time, Krystyna and I would like to wish you all belated compliments of the season and a Happy New Year. Pages 194 and 195 contain important information about the new publishers of VHF Communications.

Krystyna & Michael Wooding

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Email: andy.barter@vhfcomm.co.uk
WWW: http://www.vhfcomm.co.uk

Krystyna & Michael Wooding

Your old publishers

Goodbye

It is something of a sad time for us, saying goodbye to the magazine and to you all, many of whom we have come to know personally over the last 10 years.

However, we are leaving you in the very capable hands of Andy Barter, who has been a subscriber of VHF Communications for many years.

Andy has been sitting in with us during the publication of this, our last issue. He now has a very good knowledge base of how the magazine has been produced by us over the last ten years, and I am sure he will maintain the high standard that you all expect.

We anticipate that we may have some small involvement over the coming year with the magazine, if only to give Andy technical support with the preparation and production.

Krystyna and I wish to thank you all for the continued support you have given us over our ten years as publisher

We would also like to thank Eberhard Smolka and his staff at UKW-Berichte, the sister and founding publication of VHF Communications. We know that Eberhard will be giving Andy the same support that we have enjoyed and wish them both a successful partnership.

So that's about it. We shall now fade into the sunset and enjoy the time we have gained back.

88 from Krystyna

and

73 from Michael

Andy Barter G8ATD

Your new publisher

Hello

I am Andy Barter G8ATD, I was licenced in 1965 and am active for UHF and SHF contests in the UK, mainly on 70 cms and 23 cms. When I saw that the publication business for VHF Communication was up for sale I immediately contacted Mike Wooding. I have been taking the publication for many years and I did not want to see it disappear. The conclusion is that I am taking over publication from the beginning of 2000.

Mike has the publication process well organised so it will be easy for me to carry on with very little disruption. I do not intend to change anything that you are familiar with, so there will be :-

- The same company name K M Publications.
- The same service 4 magazine issues per year at the end of March, June, September and December plus kits from articles published.
- The same subscription price.
- The same methods of payment.
- The Web site http// www.vhfcomm.co.uk with information and secure subscription payment.

In fact, the only thing that will noticeably change will be the address:

KM Publications, 63 Ringwood Road, Luton, LU2 7BG, UK

and the telephone and fax numbers:

Tel/Fax: (0)1582 581051

If you have any suggestions about the publication that you want to make, please either write to me or send me an email.

I am planning to attend some of the UK Rallies during 2000 so that I can meet some of you, I will put details on the Web site and with issue 1/2000.

73s

Andy

Radek Vaclavik, OK2XDX

Simple Meteosat Reception Part-1: The Downconverter

1. INTRODUCTION

The Author introduces a simple system for Meteosat reception, which requires only a digital multimeter for set-up and adjustment. The system has been fully developed and tested.

The basic unit is anew downconverter, which can be used at various output frequencies. This opens satellite picture reception to a wide range of radio listeners and radio amateurs, because they can use their hand-held transceivers with WBFM mode. The downconverter was designed as a no tune unit, with all the major microwave parts etched on the PCB and containing only one small wire coil. The converter has a low noise figure and high gain. It could be used with a 60cm dish without any additional amplification.

The second part of my system is small receiver, which can be built into the cover of a Cannon-25 connector. The receiver is crystal controlled and does not need any tuning. The demodulated output signal is directly connected to the sound card in a PC. This is the best interface for picture processing as these sound cards use 13-pole digital filters.

2. DOWNCONVERTER

The system of weather satellites has been explained in many articles elsewhere and it is not proposed to go over this ground here. The most interesting satellites for weather predictions are geostationary ones. Meteosat 7, usable in Europe, transmits the WEFAX data on two channels on 1691 MHz and on 1694.5 MHz.

If you want to use a common receiver, then you need to convert the signal from 1691 MHz to the140-150 MHz range. This is the task of the downconverter. Fig.1 shows the methods of receiving and processing signals from satellites with equipment you have at home.

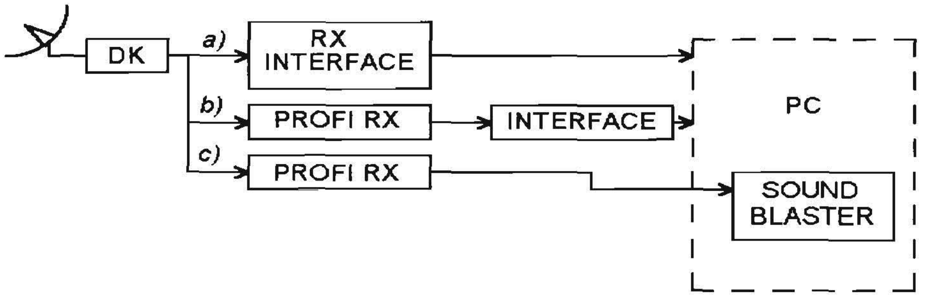


Fig.1: How to Receive and Process Weather Pictures

The simplest way is marked c) and uses your receiver and a SoundBlaster PC sound card and software. You need to build only the downconverter.

Projects published to date in [4], [5] have some disadvantages. One [4] contained a chain of multipliers that is difficult to tune. The second one [5] uses a PLL, but the downconverter has a relatively high noise figure and consequently an additional low noise preamplifier is required for good operation. [6].

At the present time there is a good selection of special integrated circuits for the 2.4 GHz ISM band. These are produced in large quantities and are thus available at reasonable prices. The heart of this converter is one of these circuits, the HPMX 5001 (IC3) produced by Hewlett Packard. It can be used for RF frequencies from 1.7 to 2.4 GHz, with an IF from 100 to 300 MHz.

In this project will be described one version of the converter with an output signal at 155.000 MHz, using a readily obtainable and inexpensive 24 MHz reference crystal.

Technical parameters:

Input frequency:	1691 MHz (1694.5 MHz)
Output frequency:	155MHz (100-200MHz)
Noise figure:	typ 1.4 dB
Gain:	>40 dB
Operating voltage:	12V

The main task of the downconverter is to amplify and convert a signal from a high frequency to lower one, which can then be received and demodulated by a VHF receiver. Usual block schematics of converters are shown in the Fig.2. In Fig.2a a design is shown with a crystal oscillator working at 100 MHz and followed by chain of multipliers. If you tune one stage incorrectly following stages will not work. Appropriate test equipment and experience for tuning this type is consequently necessary.

The second design shown in Fig.2b. shows a downconverter with a PLL. It could require just one tuning point. Older designs used discrete low-frequency components together with high-frequency dividers. This resulted in

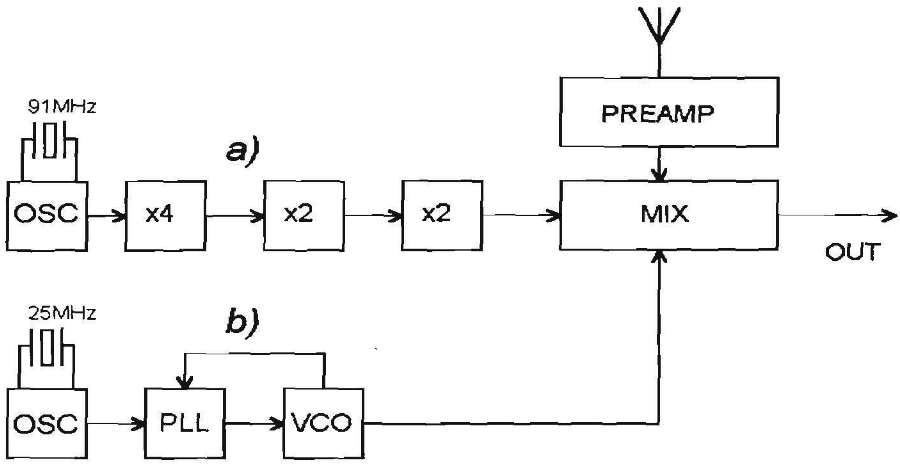


Fig.2: Possible Designs for the Downconverter

converters difficult to construct and align. Another problem was the price of microwave parts. Today we can buy cheap special devices, which are constructed using LSI techniques having all the major components in one device and requiring few discrete components.

The block schematic for the design in this project using the HPMX 5001 is shown in Fig.3. This device was designed for small data transceivers and has blocks for receiver and transmitter, for the downconverter the oscillator, buffer, multiplier, RX mixer, preamplifier and prescaler blocks are used.

The detailed circuit diagram of the downconverter is shown in Fig.4. The oscillator works at half frequency (768 MHz), the frequency being set by C16, C17, C18, L7 and D1. This signal is divided by 32 and is connected through C13 and R5 to the mixer in IC4 (NE612).

The NE612 contains a mixer and integrated oscillator. The resulting divided 768 MHz is mixed with the signal from

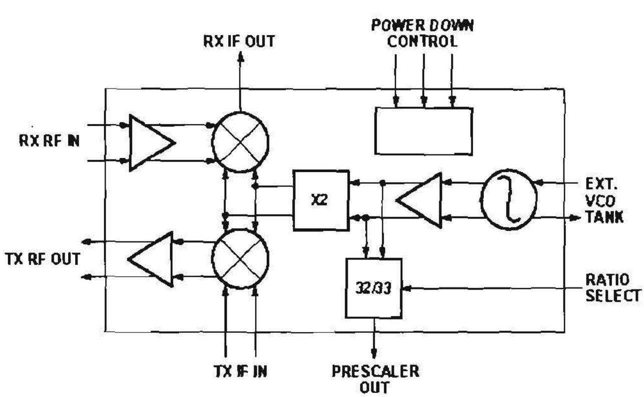
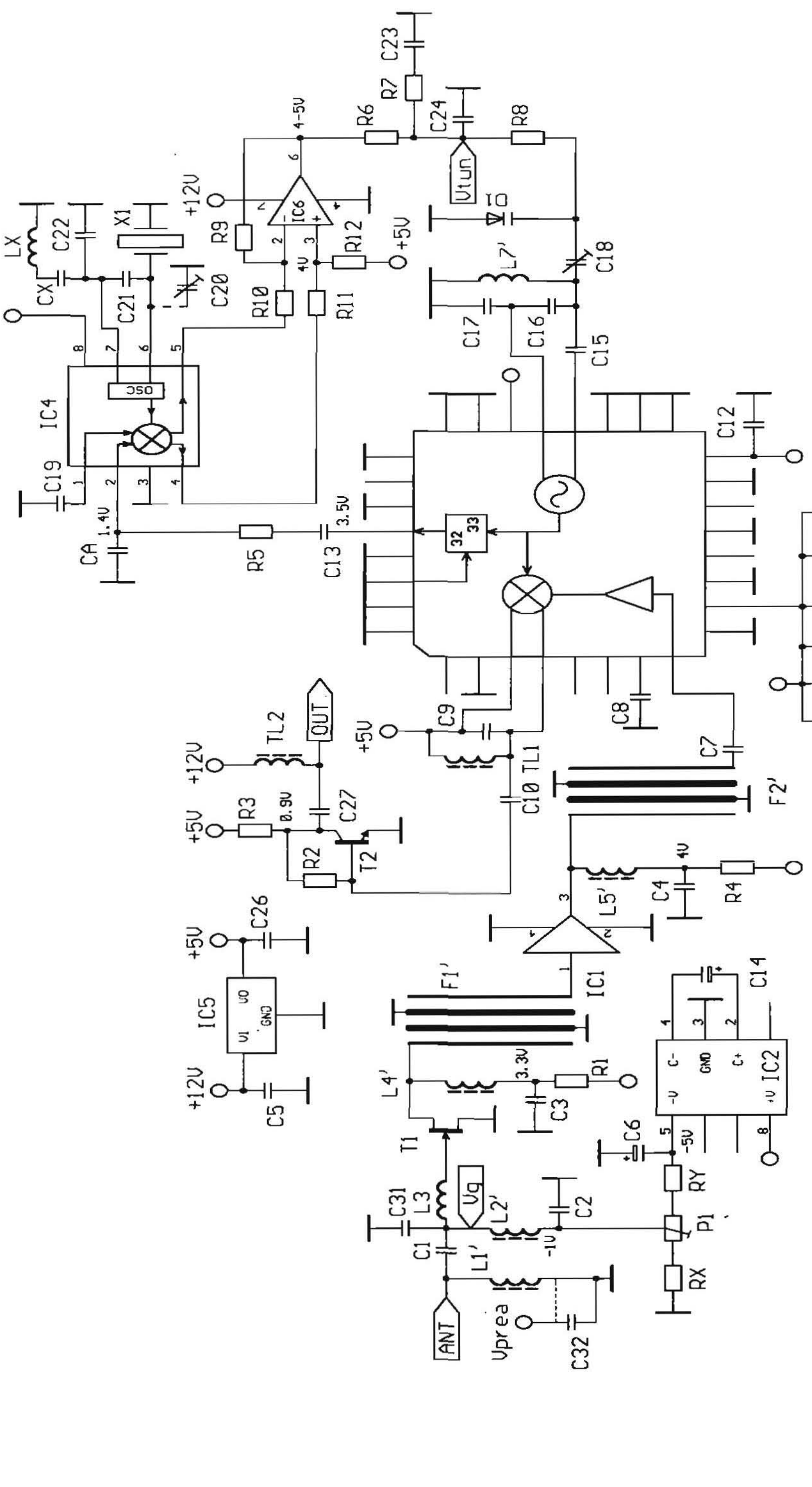


Fig.3: Block schematic of HPMX-5001



Fi.4: Downconverter Schematic

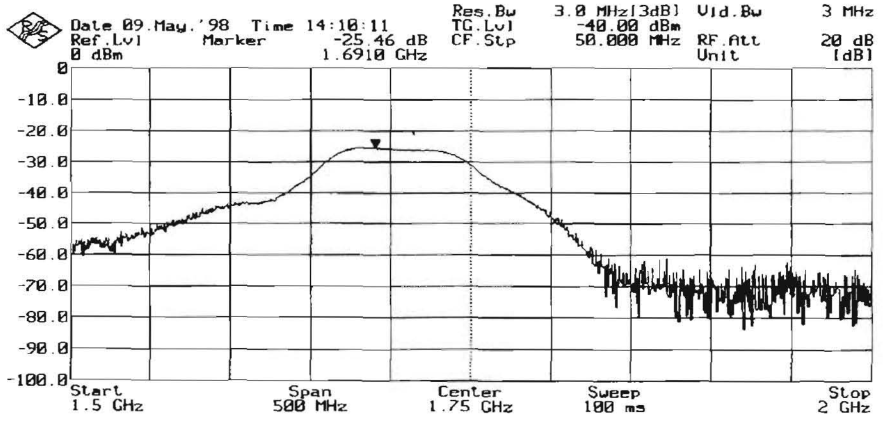


Fig.5: Measured Characteristics of 1691 MHz filter

the reference oscillator X1, C21 and C22. LX and CX should be use with an overtone crystal, do not use it with a fundamental mode crystal. C20 is used for fine tuning and can not be used if you use a crystal for the correct load capacity, or you end up with a receiver with too small a frequency step (5kHz is enough). The resultant voltage is amplified in a high-speed operational amplifier IC6 (TL071 SMD) and filtered using a simple PLL filter R6,

R7, C23, C24. The oscillator is tuned by a DC reference applied via D1. Capacitor CA was added to increase the stability of the PLL and suppress high frequency components in the output from the divider. The input signal from the antenna is connected via L3 and C31 to the GaAsFET transistor ATF-21186. L3 and C31 provide optimumx noise figure matching for T1, which is biased via L2' from the negative voltage source -5V IC2. This is a better solution than sourcing using resistors because we do not want to use unleaded (disc) capacitors. The amplified signal passes through filter F1 to monolithic amplifier IC1 (INA-03184) with its gain set at 24 dB. The signal is then routed to the mixer in IC3.

Filters F1 and F2 were optimized by PUFF. Expensive special microwave PCB material was not used because it is expensive, instead common thin laminate FR4 was utilised. Filters on this material have larger insertion losses, but this is compensated for by high gain of the IC1 (24 dB). Measured characteristics of the filter are shown in the Fig.5. and simulated in Fig.6. The filters do not require any tuning and have bandwidths off app. 100 MHz. Matching circuits were not constructed on the PCB at the input of T1, but a piece of CuAg wire was used to achieve as good a noise figure as possible.

It is worth remembering that parameters of filters depend on the PCB material. If you use non-proprietary material, the filter will be detuned and the downconverter will not perform as well.

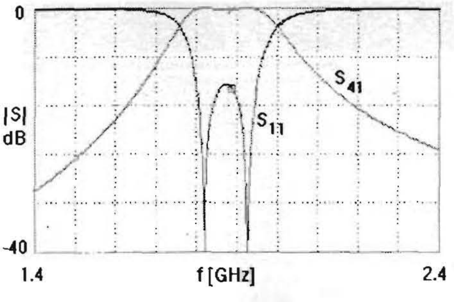


Fig.6. Simulated Characteristic of 1691 MHz filter

Grounding via holes in the PCB to the ground-plane are also very important. You will obtain oscillation instead of downconvertion without good grounding! It is strongly recommended to use good quality proprietary PCB material, although as stated earlier, this need not be expensive special microwave material.

L1, L2, L4 and L5 are quarter wave, high impedance lines for biasing and for electrostatic protection and are constructed on the PCB. The reference crystal is heat stabilised by using a PTC Thermistor.

The output signal is amplified in T2 (BF199) and fed to the output connector. IC5 MC7805 stabilises the 5V supply and the converter is fed by cable through TL2. All components marked with ' are constructed on the PCB.

If it is required to change the output frequency to match the downconverter to a specific receiver, it will be necessary to change several components. Initially the appropriate frequency crystal will need to be selected fX=(1691-fIF)/64. In the version described a common and inexpensive 24 MHz crystal was used, but a crystal can be cut for any suitable frequency. Refer to the list of components where the basic parameters of the crystal are given.

The other section to be changed will be the output filter TL1, C9. A new value will need to be calculated for the capacitor (15pF for 58.7 MHz, 2.8pF for 137.5 MHz, 2.2pF for 155 MHz). The value can be calculated using Thomson's rule f=1/(6.28*SQR(L*C)).

3. CONSTRUCTION AND ALIGNMENT

The downconverter is installed in a shielded metal box 92 x 67 x 22mm. Trim the PCB to fit the box by filing and prepare holes in the box for the connectors. Ensure good grounding via holes at emitters of T1 and IC1.

Next instal voltage regulators IC5 and IC2 with appropriate passive components and check their correct function by checking the output voltage.

Now carefully solder IC3, IC4, IC6 and their passive components. For C18 use a small trimmer. Varicap D1 is soldered onto the bottom side f the PCB with as short leads as possible. Ca is soldered directly to pins-2 and 3 of IC4 from bottom side. IC3 requires special care whilst soldering. After a careful check for short circuits and un soldered leads connect downconverter to regulated power supply though an ammeter the current should not exceed 100 mA.

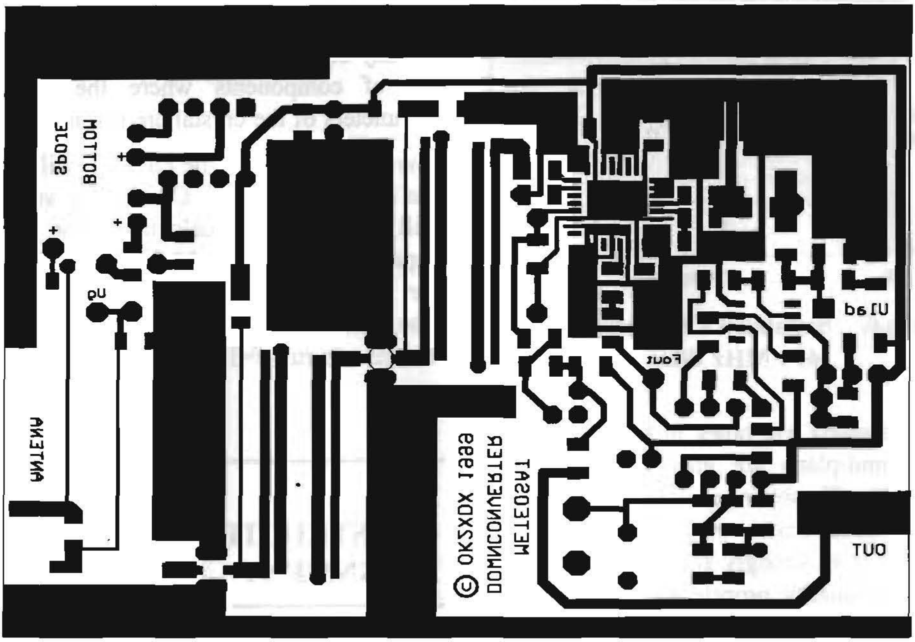


Fig.7: PCB Layout - top (not to scale); size: 92 x 67 mm

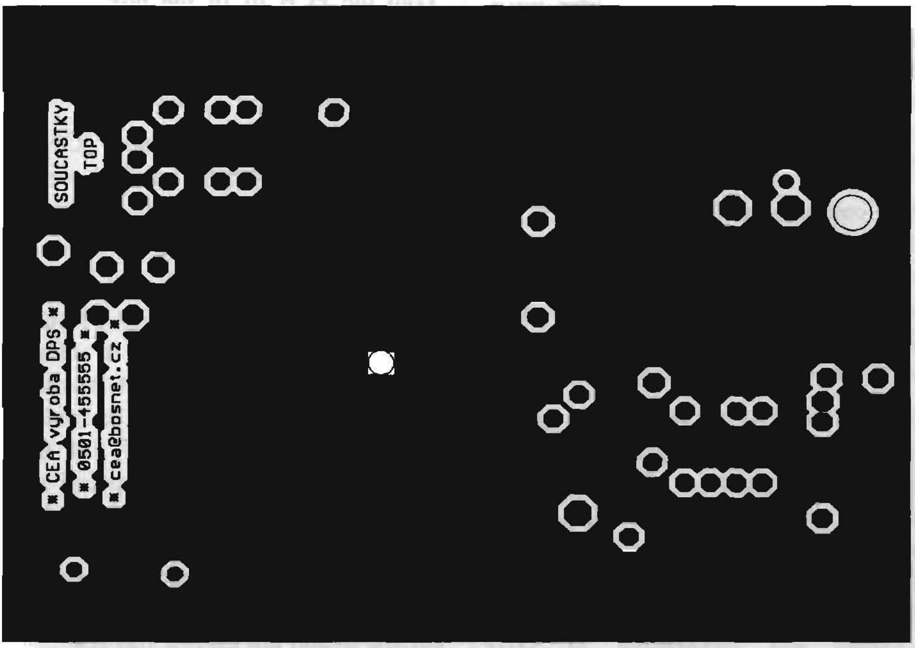


Fig.8: PCB Layout - bottom (not to scale) size: 92 x 67 mm

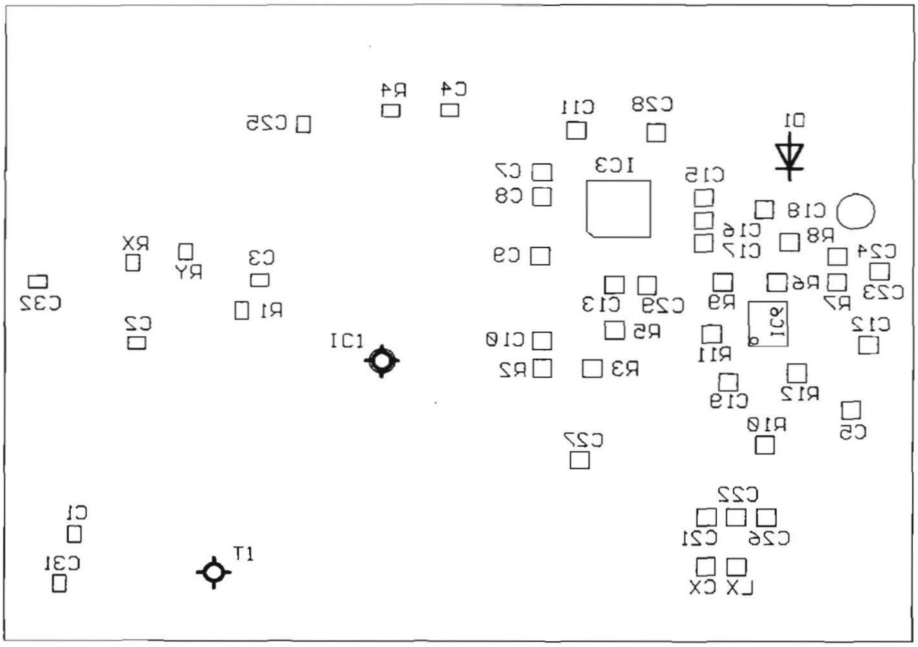


Fig.9: Component Overlay - bottom side

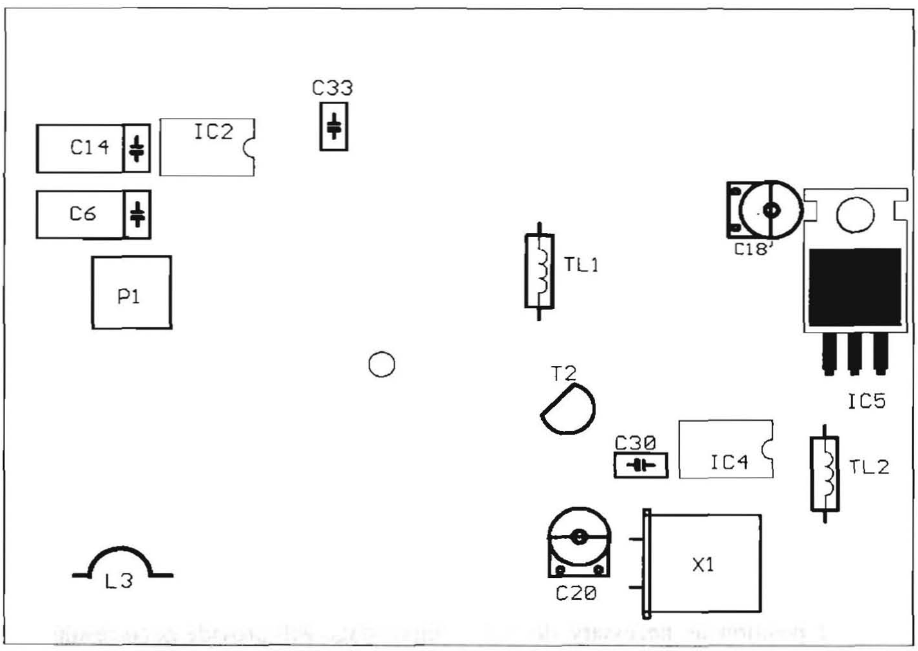


Fig.10: Component Overlay - top side

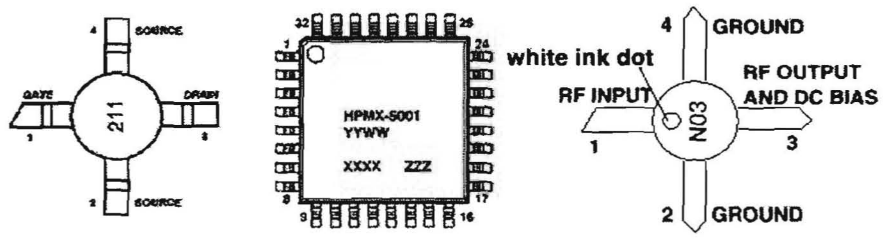


Fig.11: Semiconductor pin-outs

Now set C20 to mid-point (if used) and C18 to minimum value. Connect a digital voltmeter to point Ulad (tuning voltage) and using a plastic screwdriver slowly increase capacity of C18. The voltage will suddenly change to a higher value, indicating that the PLL is in lock. Now if you detune L7 by close coupling using a finger the tuning voltage should increase, the PLL. The PLL will maintain lock over the voltage range of 3-9V. Adjust C18 to set this voltage to app. 4.5 V. Switch off and on again and confirm that the PLL locks without problem. If not gently adjust C18 until this condition is met with the voltage as close to 4.5V as possible..

Now solder the output amplifier T2 and input amplifier, with IC1 on the bottom side of the PCB. Then check voltage on R4, which should be app. 1V. The packages of the semiconductors used are shown in Fig.11. Next the PCB is installed into the metal box. Initially solder the input and output connectors, N, BNC or SMA types can be used, which preferably should be soldered to the box. Now place PCB into the box, centre leads of connectors have to hit the right places on the board so adjust the position as necessary do not use any additional wires to connect the input signal from the antenna socket to the PCB! This will increase the noise figure. Solder PCB into the box from both sides and around all edges.

Now set up Ug voltage by adjusting P1 to -1V and carefully solder transistor T1 on the bottom side. Conctruct L3 from 0.6mm of CuAg wire, half turn, diameter 10mm and solder it on the component side.

Connect the downconverter to the antenna and tune the receiver to correct frequency. If you are unable to find a signal try to measure actual frequency of the VCO and then recalculate the correct RX frequency or try to tune +/-1 MHz around until you hear a typical Wefax signal. Try to achieve as low noise in the signal as possible by adjusting P1. Be careful and do not exceed maximum drain current or Vgs-max (-4V). After this, try to bend L3 down to PCB for minimum noise in signal. This will be achieved with app. 1mm distance between L3 and the PCB. If you receive a strong signal, detune it by rotating the antenna out of the satellite and adjust again. During this stage it will be appreciated that a high-gain antenna and well constructed input stage will provide good results.

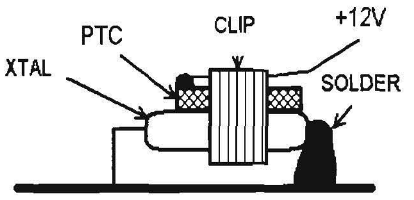


Fig.12: Mounting of PTC on Crystal

The final thing is to mount the PTC Thermistor onto the crystal as can be seen in the Fig. 12. Temperature stabilisation is necessary to give good results. It must be considered that a frequency change of 78 Hz of the reference oscillator will cause a 5 kHz change in the output frequency.

4. IDEAS FOR THE FUTURE

All electronic constructions age very fast. At the present time I would design an even easier to construct converter around newly obtainable Motorola components. These circuits are also available at relatively low prices.

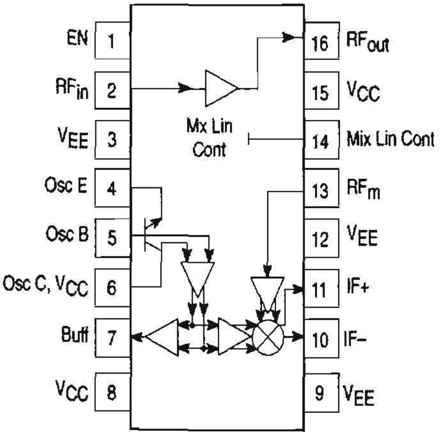


Fig.13: Block schematic of MC13142

In the design described here four ICs (IC1,3,4,6) with a total price of around £12.00 could be replaced by only two modern RF circuits from Motorola with a total price of around £8.00. The first circuit is MC13142 which contains a low-noise preamplifier, double balanced mixer (with controlled linearity) and VCO. Its basic schematic is shown in Fig.13. The basic parameters are: RF, LO, IF frequency range: 0-1800 MHz, LNA noise figure: 1.8 dB, LNA gain: 17 dB, mixer gain: 9 dB.

Detailed info including the PCB layout can be found on Motorolas WWW site. This circuit could be used for various applications, such as receivers, down-converters and data or speech transceivers.

The second circuit, which would replace mixer IC4 and amplifier IC6, is the MC12179. It is single channel frequency synthesiser operating from 500 to2800 MHz. Its expanded block diagram is shown in Fig 14. The circuit contains a crystal oscillator, prescaler to 2.8 GHz, phase detector and charge pump. Operating voltage is 5V and supply current 3.5mA. Recently I tested this circuit and it worked perfectly.

The MC12179 is an ideal solution for various converters for Meteosat or for TV broadcasting in the 2.2 GHz band, as no complicated external microprocessor control is required. All these circuits were designed for the minimum of external components. In Fig.15 can be seen an example of a converter for the 1.9 GHz band. This design does not contain any tuning capacitor or coil.

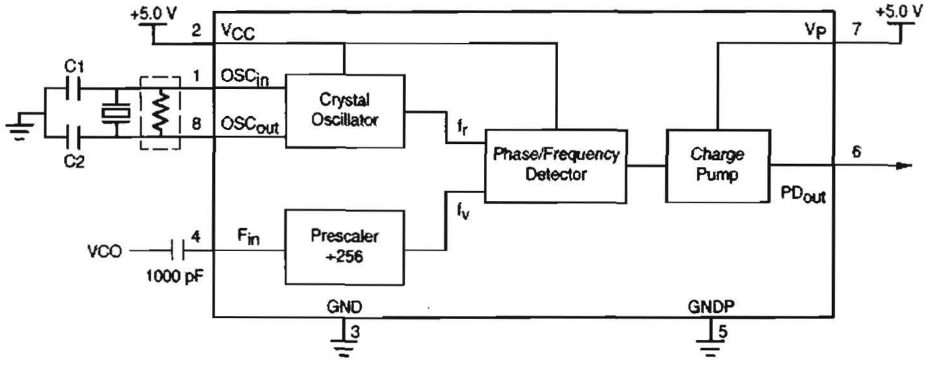


Fig.14: Simple Synthesiser using the MC12179

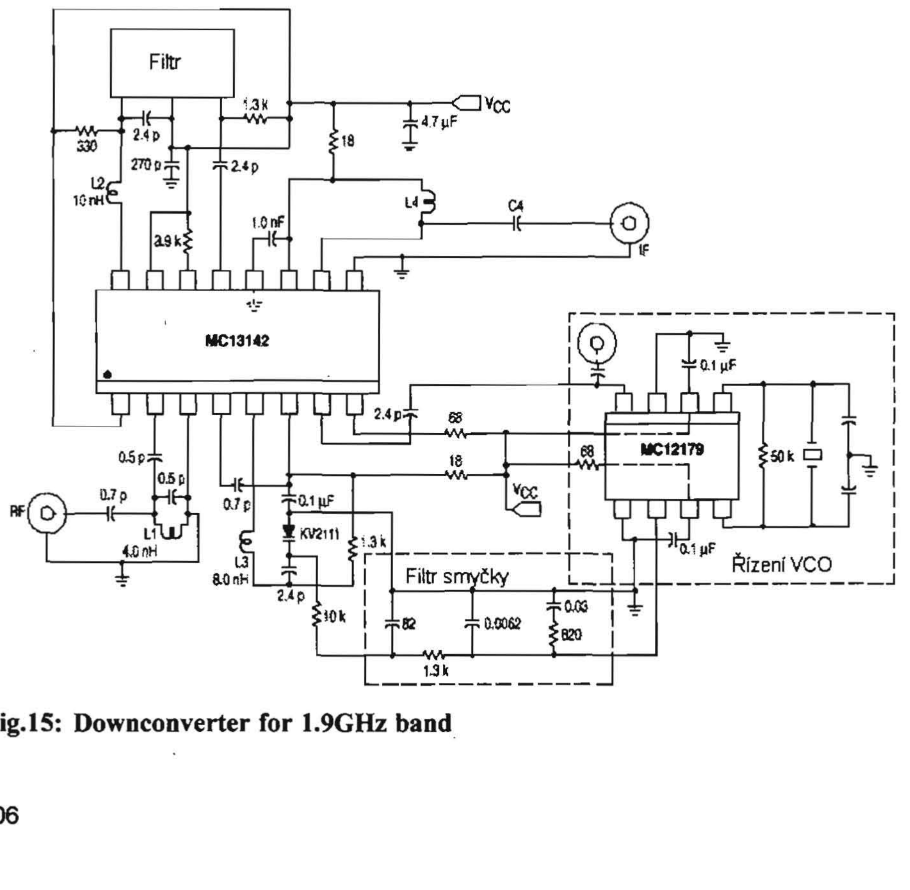


Fig.15: Downconverter for 1.9GHz band

5. PARTS LIST

(see text for changes with different output frequencies)

Capacitors: ceramic - SMD 1206

C1	100p
C2, C3, C4, C10, C11, C12, C19 C25, C27, C32	1n
C5, C26, C28, C29	47n
C7	2p7
C8	3p3
C9	2p2
	15pF for 58.7MHz, 2.8pF for 137.5MHz 2.2pF for 155MHz
C13	12p
C15, C16, C17	5p6
C21, C22	1p8

CX see text (used with overtone crystal)

C18 trimmer capacitor 6p mini, 2 leads, SKY or Philips

C20 trimmer capacitor 10p mini, 2 leads, SKY or Philips

C6, C14	22µF / 6V
C30	10µF / 6V
C33	47µF / 6V
CA	47pF

Resistors SMD 1206:

R1	47Ω
R2	3k3Ω
R3	1kΩ
R4	100Ω
R5	22Ω
R6	10kΩ
R7	5.6kΩ
R8, R10, R11	33kΩ
R9, R12	68kΩ

RX 1.5kΩ or 0Ω (then be careful with Vg setting, Vg has to be in the range -0.5 to -4.0V

RY 4.7kΩ or 0Ω (then be careful with Vg setting, Vg has to be in the range -0.5 to -4.0V

P1 adjustable resistor 10kΩ

Semiconductors:

D1	BB405B
T1	ATF-21186
T2	BF199
IC1	INA-03184
IC2	ICL7660
IC3	HPMX5001
IC4	NE612 (SA612)
IC5	7805
IC6	TL071SMD

Others:

L3 0.5 turns CuAg 0.6mm, dia. 10mm

LX see text (used with overtone Xtal)

TL1 0.47µH see text

TL2 47µH

X1 24 MHz, see text, or parallel resonance, fundamental mode,

Cl=32pF, accuracy +25ppm for 60deg C (if you use PTC), stability +25ppm in 10-40 deg C

Thermistor PTC Siemens A60, B59060-A60-A10

Radek Vaclavik, OK2XDX

Simple Meteosat Reception Part-2: A Simple Mini Receiver

1. INTRODUCTION

The downconverter described in this article could be used with a wide range of output signals. Common handheld transceivers, wideband receivers could be used if they feature wide FM mode. However, this equipment is not cheap and often other features are degraded. Consequently a simple 2,-channel receiver is now described which could be used with the converter for receiving Meteosat 7.

This receiver does not need a big display and a lot of LED diodes, simplicity is more important. The receiver is crystal controlled and could be built in the small cover of a Cannon-25 connector.

The diagram of the simplest way to receive geostationary satellites is shown in Fig.1. The output frequency from the downconverter is set to 58.7 MHz, determined by using a 48 MHz crystal and 10.7 MHz first IF. The 48 MHz crystal is easy to obtain and inexpensive. If it is required to receive both channels, a new crystal at 51.5 MHz must be added.

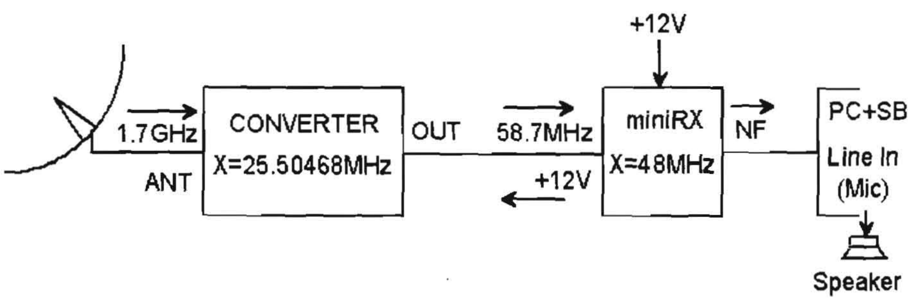


Fig.1: The simplest method of Meteosat Reception

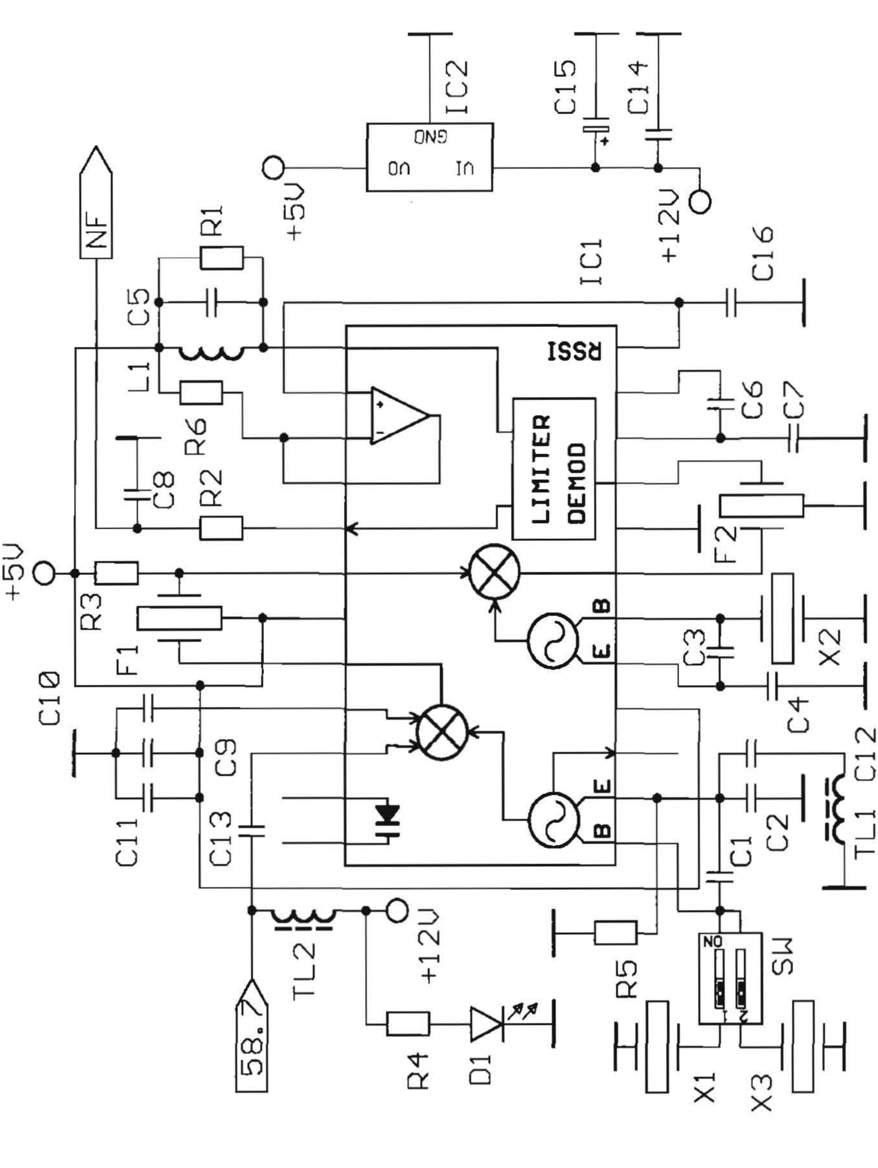


Fig.2: Circuit Diagram of the Receiver

2. DESCRIPTION

Parameters:

Input frequency: 58.7 MHz (62.2 MHz)

Sensitivity: 1.5uV

Type: superhet (10.7 MHz, 455 kHz)

Bandwidth: 30kHz

Output audio: 1.2Vpp (9kHz deviation)

Current consumption: 12mA

A detailed schematic of the receiver is shown in Fig.2.

The receiver is based on the MC13135 which is the replacement for the MC3362 [8]. The input signal is fed through C13 to the first mixer. The first oscillator is controlled by X1 (X3) and R5 increases current to the internal transistor.

The the signal then is filtered in F1 (10.7 MHz, bandwidth 200 kHz) and mixed to the second IF 455 kHz. Filtering is carried out in F2 (455 kHz, 30 kHz) and demodulated in L1, C5. The resultant signal is fed from R2 and C8 to the WEFAX demodulator, for example to the sound card in PC.

The receiver does not need excellent sensitivity due to high gain of the downconverter.

An RSSI signal (receive signal strength indicator) is available on pins-15 and 16. Approximate voltage with a 60cm dish is 0.65V and with two stage preamplifier is about 0.9V.

The receiver is powered from a small regulator MC78L05. An LED diode D1 indicates the 12V voltage. The converter is fed through Tl2 and the coaxial cable. Power supply has to provide a current of about 700mA for few seconds then about 300m, the initial higher current is needed for PTC warming up. Voltage could be from 10V to 14V.

The receiver is very small and does not feature any output amplification. This is left to the sound card software drivers in the PC.

If you want to receive both channels on Meteosat, you have to add X3. Parameters are: 51.500 MHz, serial resonance, 3rd overtone, accuracy +25ppm for 25 deg C, stability +25ppm in 10-40 deg C.

The PCB layout is shown in Fig.3. The receiver uses both SMD and standard component types. The component layout is shown in Fig.4. Crystals and coils should be folded over to lay against the PCB.

Adjustment of the receiver is very simply. Turn coil L1 for the maximum noise or to the symmetrical signal with an oscilloscope. It is recommended to use the original 455 kHz LC demodulator.

The sensitivity can be checked using a signal generator, but it is not necessary. If the receiver does not work, try to measure the first oscillator with X1 by using a frequency counter, oscilloscope or receiver (3rd harmonic is 144 MHz).

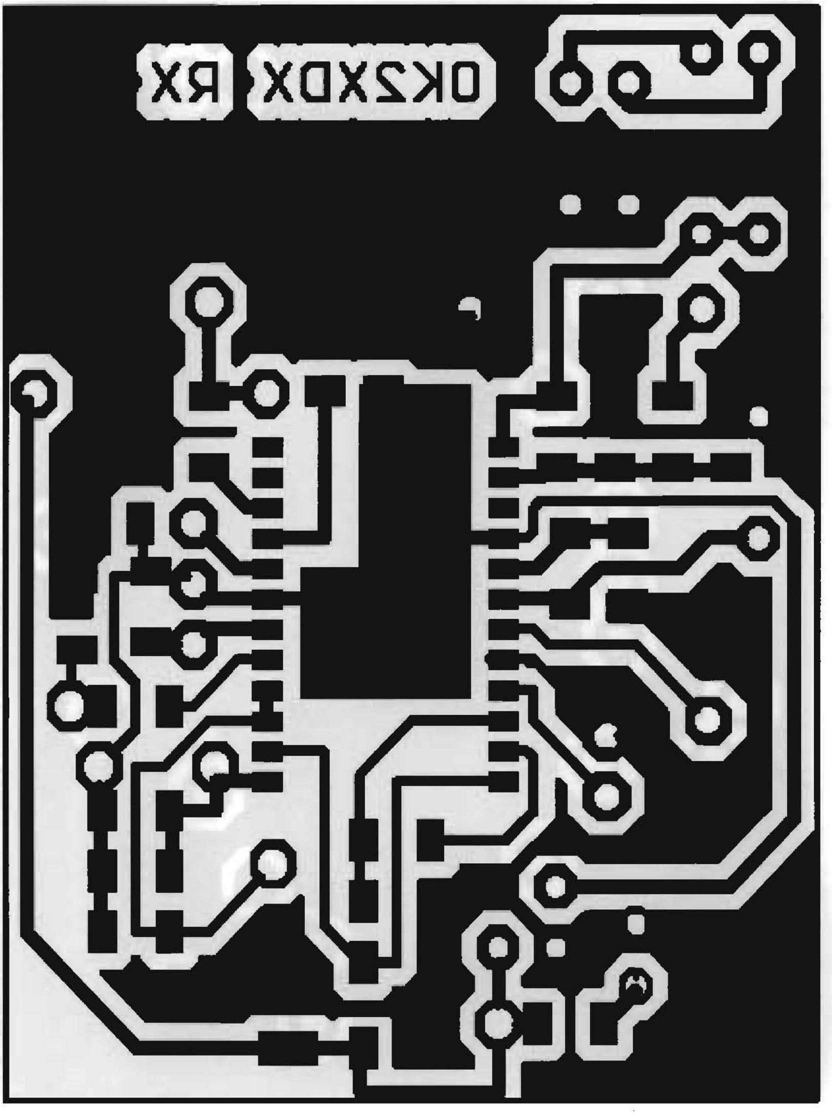


Fig.3a: PCB layout, bottom (not to scale)

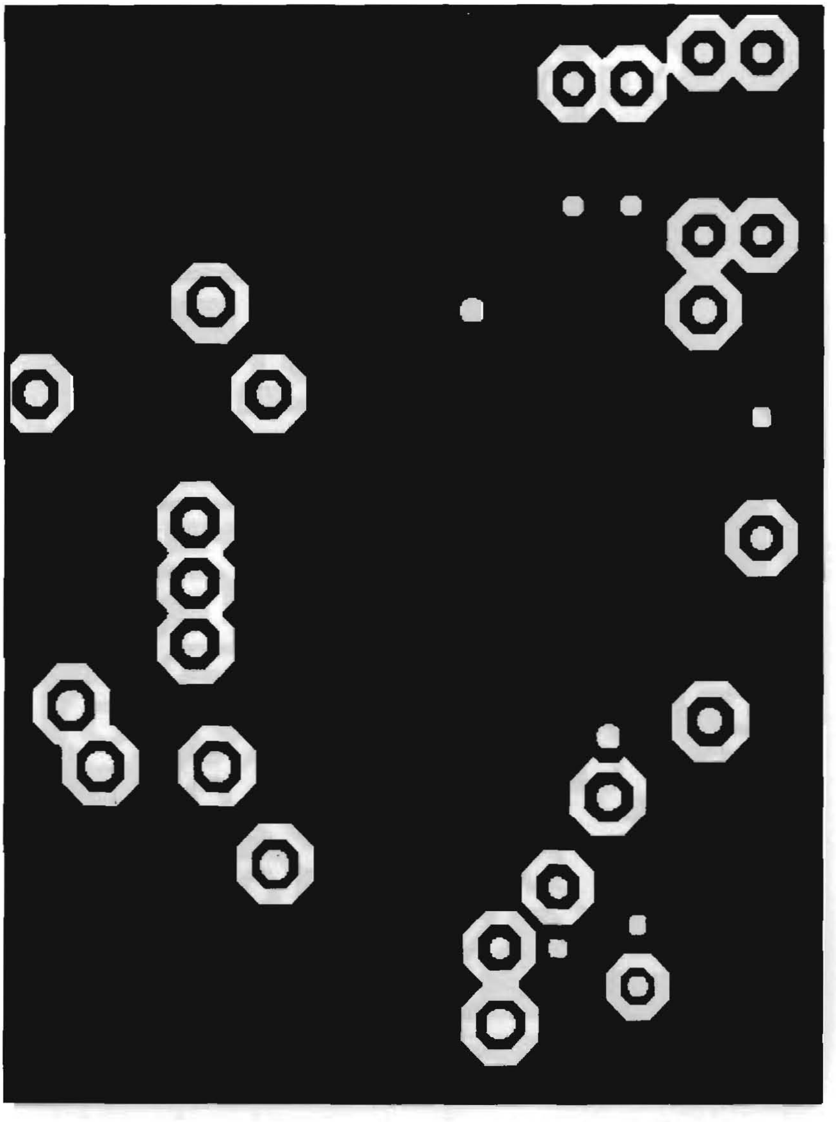


Fig.3b: PCB layout, top (not to scale)

3. CHANGES REQUIRED IN THE DOWNCONVERTER

If you want to use this simple receiver and the converter on 58.7 MHz, some small changes need to be made in downconverter.

The first one is a change of crystal in the converter, the parameters are: 25.504687 MHz, parallel resonance, fundamental mode, Cl=32pF, accuracy +25ppm for 60deg C (if fitted with a PTC resistor), stability +25ppm in 10-40 deg C.

The second change is retuning of the output filter. Experiments show that receiver needs some selectivity to remove spurious signal, otherwise these signals decrease sensitivity, consequently one more coil is required.

The detailed schematic is shown in Fig.5, the added components are marked with an X suffix. TL1, TLX 100nH; C9, CX1 56pF and C10, CX2 12pF. SMD capacitors and inductors are preferred, otherwise TL1 and TLX must be constructed as 8 turns of 0.3mm Cu wire on 3mm diameter, do not spread windings. The PCB will need to be slightly modified for the new C10 position.

4. SOFTWARE FOR DEMODULATION

I could write another article about WEFAX demodulation. These days it is quite a simple matter to use the sound card in your PC. It is a common and cheap part of most of computers and sound card drivers have good digital filters implemented in them. There is only one limitation in the speed of computer, minimum specification is 486DX/66MHz.

I tested the DOS program JVFAX with a soundblaster driver by Oded Regev, 4Z5BS and it works extremely well. New software, JVCOMM32, by Eberhard Backeshoff, DK7JV for Win95 and Win98 enables the sound card, too. It can work in a multitasking environment and the filtering appears better that in the DOS driver. These software programs can be found at: http://www.jv-comm.de.

Correct setting of the sound card is very important for good functioning of the JVFAX driver. This could be problem, especially in DOS, where you will need a program such as SetMixer, which can be found it on the WWW site of the manufacturer of your sound card if it, or something simpler, was not included with your sound card.

5. CONCLUSION AND EXPERIENCES

The downconverter and the receiver are one of the simplest methods of receiving on-line weather pictures from satellites. Quality components, good PCB material and careful work are the basis for success. A digital multimeter is only piece of test equipment you need for adjustment and setup.

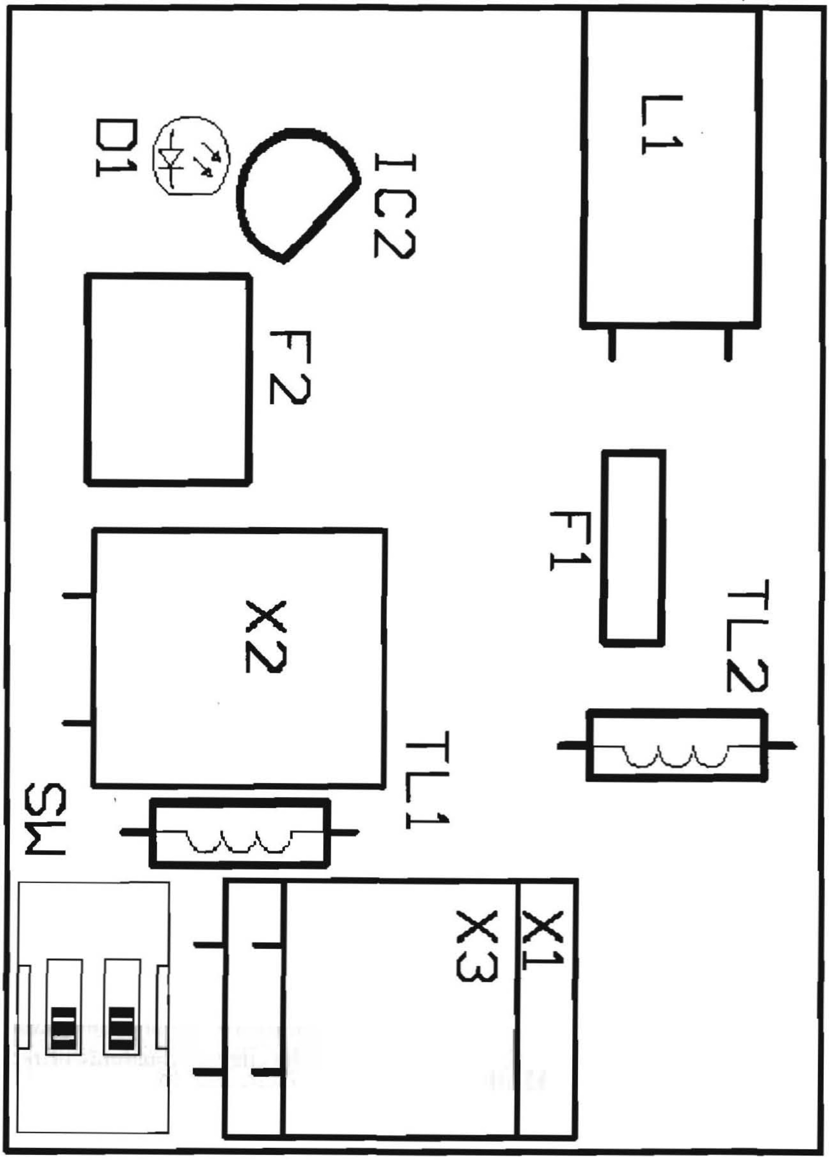


Fig.4a: Component Overlay, bottom (not to scale)

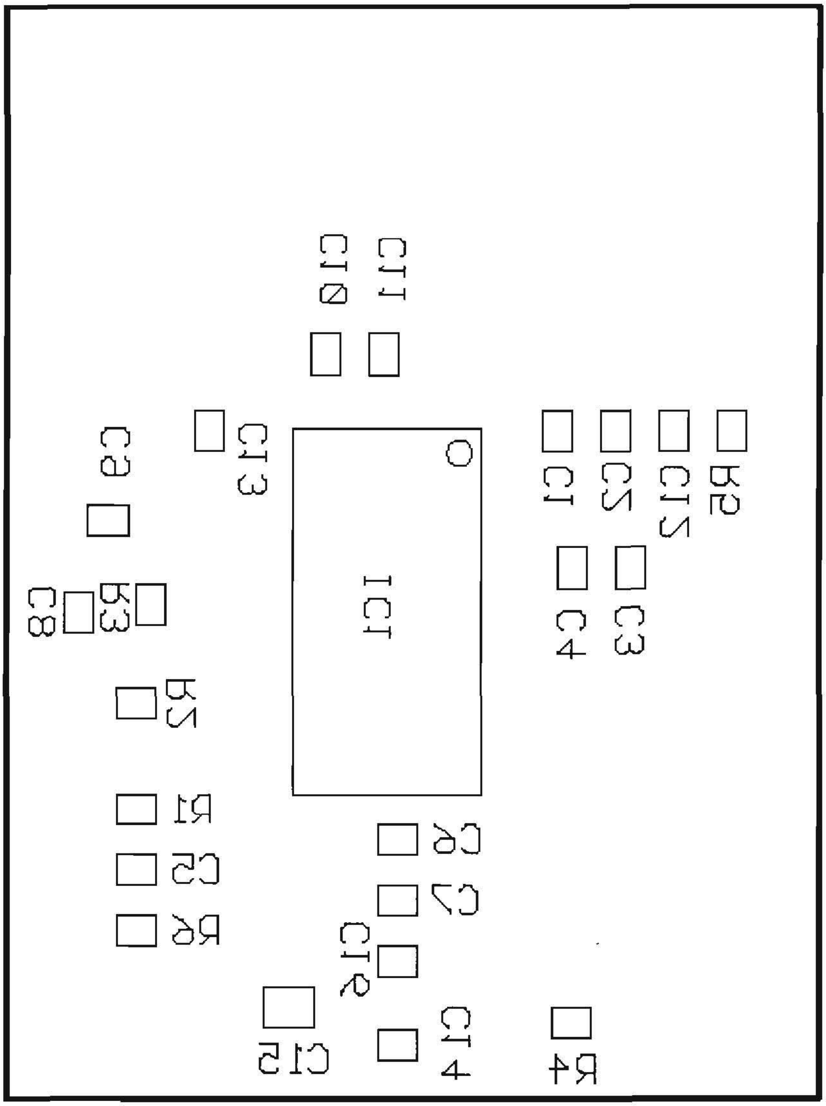


Fig.4a: Component Overlay, top (not to scale)

To date there are over 20 of the converters working in the Czech Republic. All are working ok and there were no problems during adjustment. Reproducibility of the system is good.

Experience has shown that coil L3 needs to be bent as close to the PCB as possible, to achieve as low a noise figure as possible. The ideal distance is about 1mm above the board. Be careful with different types of GaAsFET input transistors that have different optimum NF matching.

The system was tested in Czech republic with a 60cm dish. The signal was clear, but some noise appeared during periods of heavy cloud cover.

For really clear reception it is recommended that at least an 80cm dish or preamplifier is used. The PCB is prepared for powering a preamplifier. Simply cut the ground end of L1 and connect 12V in parallel with C32.

The preamplifier could solve your problems with temperature stabilisation, because with sufficient gain, you could place the downconverter under the roof or at bottom of the feeder, instead of mounting it at the antenna. Designs for suitable preamplifiers are many and varied.

Further details on these two projects and Meteosat reception can be found on my WWW site at:

http://www.qsl.net/ok2xdx

6. LITERATURE

[1] Hewlett Packard datasheets .

[2] Philips datasheets .

[3] PUFF manual

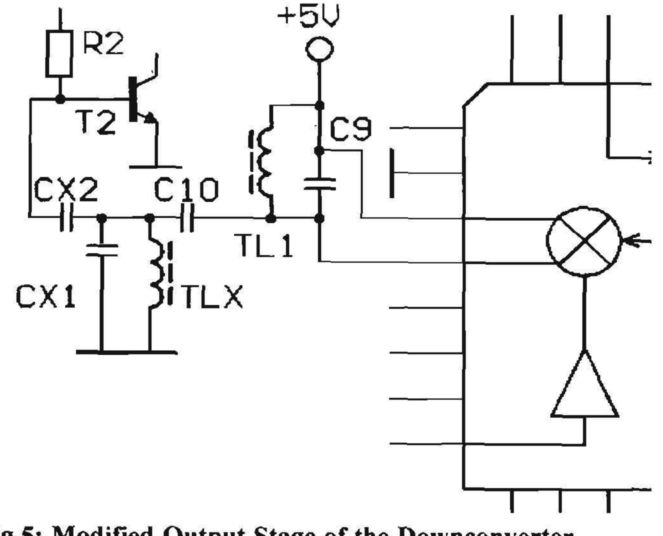


Fig.5: Modified Output Stage of the Downconverter

[4] Barkowiak, B: Rauscharmer Meteosat-Konverter mit GaAs-FET, Vor- und Michstufe, UKW-Berichte 1/1985, s.22.

[5] Vidmar, M: Sprejem APT-WEFAX slikic s satelita Meteosat. CQ ZRS, leden 1995.

[6] Vidmar, M: Ein sehr rauscharmer Antennenverstarker fur das L-Band, UKW-Berichte 3/1991.

[7] Vaclavik, R: Prijimac a interfejs pro prijem meteosatelitu. PE A-Radio 3/1997.

[8] Vaclavik, R: MC3362, MC3363 konci. PE A-Radio 3/1999.

[9] Vaclavik, R: Prijem geostacionarnich meteosatelitu, PE A-Radio 05/1997.

[10] OK2XDX's homepage on internet, http://www.qsl.net/ok2xdx

7. PARTS LIST

Capacitors (SMD, 1206)

C1,2	27pF
C3	47pF
C4	120pF
C5 for 455kHz demodulator	
C6,7,9,11,14,16	100nF
C8	47nF
C10,12,13	1nF
C15	10µF / 16V

Resistors (SMD, 1206)

R1	39kΩ
R2	1kΩ
R3	330Ω
R4	1kΩ depends on LED
R5	33kΩ
R6	10kΩ

Semiconductors:

D1	LED
IC1	MC13135DW
IC2	78L05

Others:

F1 Filter 10.7 MHz / 200 kHz
F2 Filter 455 kHz /30 kHz (suffix B)
L1 455kHz demodulator circuit

SW	double DIP switch
T1	1H, SMCC choke
TL2	47H, SMCC choke
X1	48 MHz
X2	10.245 MHz
X3	51.500 MHz, series resonant, 3rd overtone, accuracy +25ppm for 25 deg C, stability +25ppm in 10-40 deg C

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Storage Normaliser For Spectrum Analysers

1. Displays for Spectrum Analysers

Spectrum analysers usually produce large quantities of information that can be properly represented only on a fully graphic display. The latter can be a simple oscilloscope CRT display, a raster-scan CRT or a dot-matrix LCD. Many older spectrum analysers were equipped with delicate and difficult-to-use CRTs with a special storage screen. Newer spectrum analysers have digital video memories and usually provide a hardcopy option, either with a built-in printer or through a general computer interface.

Unfortunately, new display technologies do not necessarily mean improvements of the overall instrument performance. In particular, in the case of radio-frequency spectrum analysers, all engineers appreciate the good old analogue oscilloscope displays. New spectrum analysers, including the highest-priced models, all include digital displays that have both too low resolution and too slow display update.

Of course, the best solution is to have both analogue and digital display technologies available in a single instrument. An older spectrum analyser or a home-made instrument with an analogue oscilloscope display can easily be upgraded with an additional storage-normaliser unit. Since the latter can bewitched in and out as required by the particular measurement, it allows the advantages of both display technologies in a single instrument.

A storage-normaliser is particularly useful while using a tracking generator as shown in Fig. 1. In the latter case, the response of the tracking generator, spectrum analyser and other test equipment is stored in digital memory during system calibration. The response of the device-under-test (DIRECT) can then be quickly compared with the stored system response (MEMORY). Since most spectrum analysers provide a logarithmic video signal (usually 10dB per division), a simple subtraction of the system response from the measured trace (DIFFERENCE) removes any system influence on the measured device response.

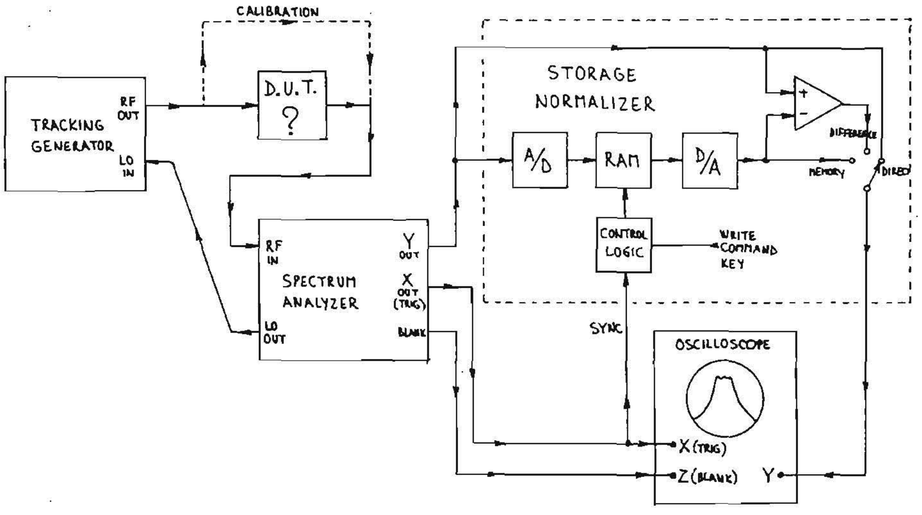

Fig.1: Principle of Operation of a Storage-normaliser

2. Storage Normaliser Design

A simple storage-normaliser is described in this article, to be used with the spectrum analyser described in [1] or [2] or other similar instruments. Since the narrowest resolution bandwidth of the abovementioned spectrum analyser is only 10 kHz, very slow frequency sweeps are usually not used. A digital storage is therefore not required for faster frame refresh at very slow sweep times.

The design of the storage-normaliser is much simplified since the display always operates at the same sweep frequency as the spectrum analyser. All required clock and address signals are generated by simple and fast hardware logic in place of a much slower microcontroller. Fast A/D and D/A converters and a sufficiently large memory allow high-quality images to be stored in the video memory.

The video bandwidth of the spectrum analyser ([1] or [2]) amounts up to 500 kHz without any video filtering. To avoid any video degradation, a sampling frequency of 1 MHz was selected. A sampling frequency of 1 MHz is far too high for most microcontrollers. Therefore simple control logic with 74HCxxx circuits generates all required clocks and addresses.

The dynamic range of the logarithmic detector amounts to almost 100dB. Inexpensive 8-bit A/D and D/A converters therefore allow a resolution of about 0.4dB for the storage-normaliser. A resolution of 0.4dB is comparable to the accuracy of the 10-stage logarithmic detector presented in [1] or [2].

The A/D and D/A converters as well as the video memory are shown on Fig. 2. The A/D converter TDA8703 is an 8-bit

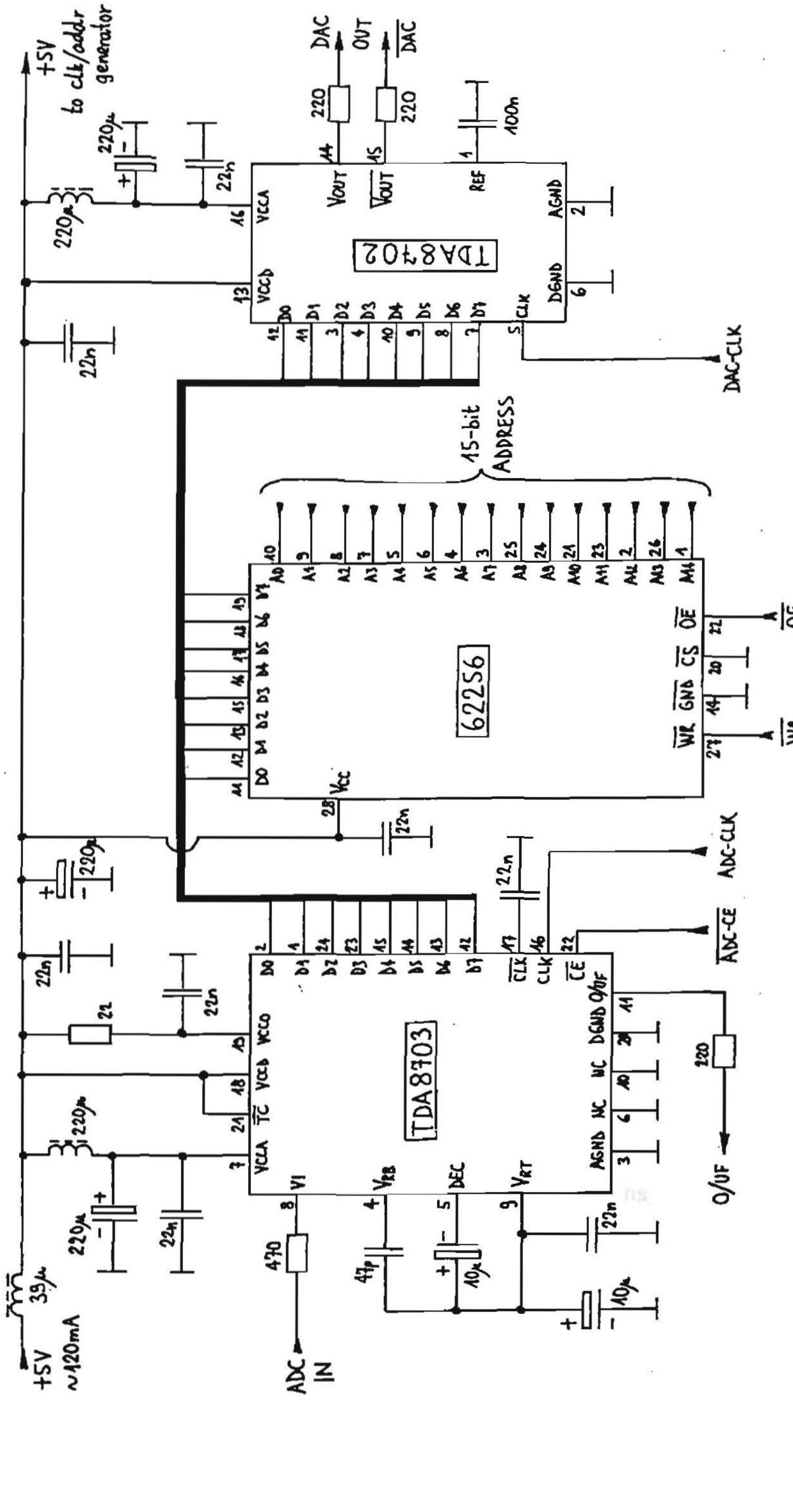

Fig.2: A/D and D/A Converters and Video Memory Circuit

flash A/D converter that allows sampling frequencies up to 30 MHz. Flash A/D converters include a comparator for each step of their transfer function, in total 255 comparators in an 8-bit A/D converter. Their main advantage is very fast operation. Also, flash A/D converters do not require a critical sample-and-hold circuit on the analogue input.

The TDA8703 has three-state outputs to be connected directly on an 8-bit data bus. The O/UF (over/underflow) is an additional output that goes high whenever the input-signal level is too low or too high, in other words outside the normal operating range of the A/D converter.

While testing the circuit of the storage-normaliser it may be useful to connect a LED from the O/UF output to ground, of course Through the 220Ω current-limiting resistor.

The 62256 is a 32768-byte static CMOS RAM. At a sampling frequency of 1MHz it can store about 32 ms of video signal. The storage-normaliser is intended to be used at a sweep speed of 2ms/division for a total sweep time of 20ms, resulting in 20000 samples or 20000 bytes to be stored in the video memory. The 62256 has eight common input-output pins D0...D7 that can be tri-stated and connected directly to an 8-bit data bus.

The TDA8702 is a fast 8-bit D/A converter. It includes an internal 8-bit latch on the digital inputs. Data transfer is triggered by the DAC-CLK, so that the same data bus can also be used for other purposes. The TDA8702 has two complementary analogue outputs. Both outputs are used in the storage-normaliser to further reject noise and voltage variations on the +5V supply line.

The A/D and D/A converters as well as the memory require several steering signals. The clock/address generator is shown on Fig.3. All clocks run at 1MHz, but have different pulse widths and phases. All clocks are obtained from a 8MHz crystal oscillator driving a 8-bit shift register (74HC164).

The shift register is connected as a frequency divider by 8. The different clocks are obtained from the 74HC164 outputs through a few NAND gates (two 74HC00).

The A/D converter TDA8703 performs one conversion for each ADC-CLK pulse. The outputs of the TDA8703 are then enabled by the /ADC-CE signal. Writing to the memory is enabled with /WR while reading from the memory is enabled by /OE. Finally the byte from the memory is copied into the D/A converter TDA8702 with DAC-CLK. When all clocks are disabled, the output Q0 of the 74HC164 increments the address counter.

The address counter includes four synchronous counters 74HC161. The TRIG pulse coming from the spectrum analyser signals the start of the sweep. After the TRIG pulse is "cleaned" in a D-flip-flop (one half 74HC74), it resets the address counter. The address counter supplies a 15-bit address to the memory. The last counting stage (Q3 of the last 74HC161) is used to stop the address counter until the next trigger pulse.

Writing the video data to memory is enabled manually by depressing the

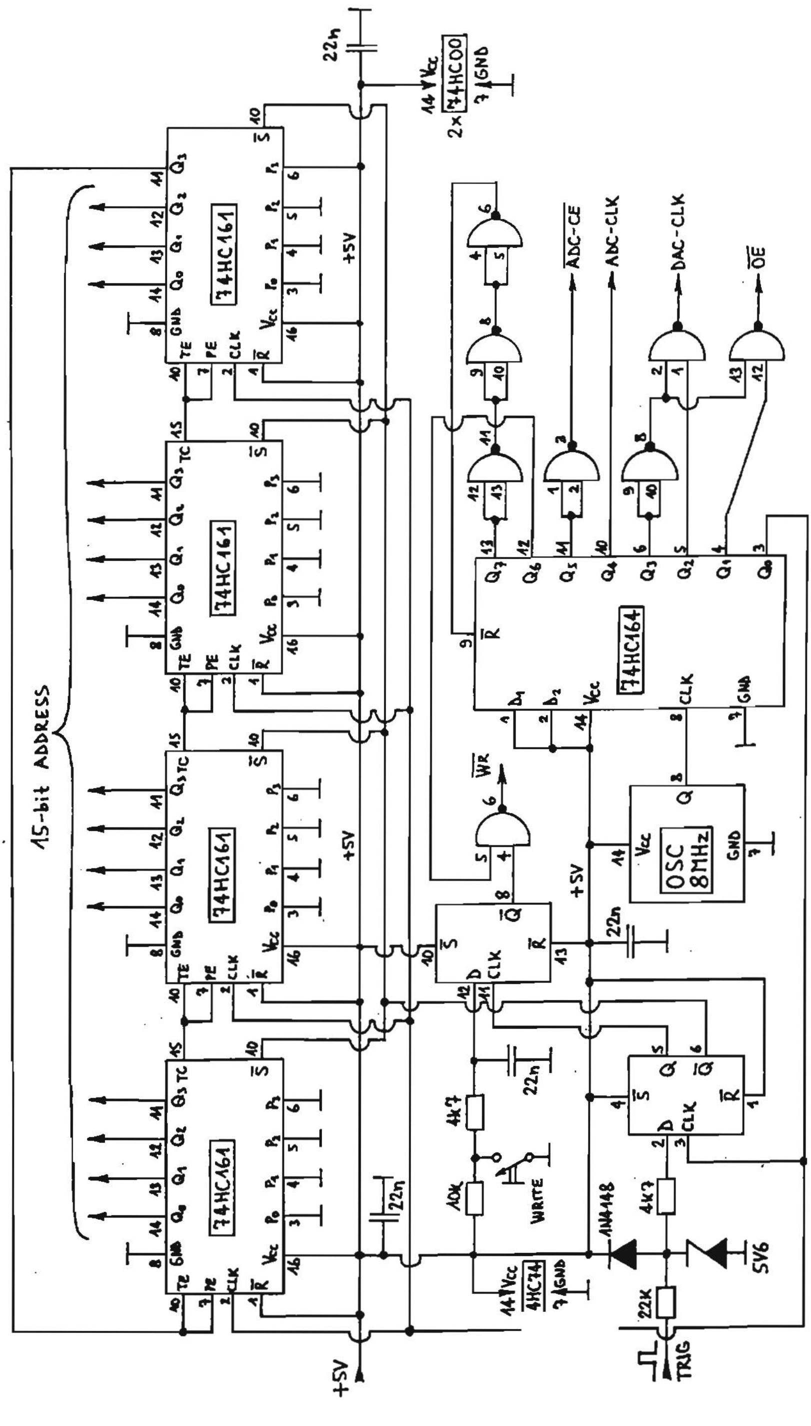

Fig.3: Clock / Address Generator Circuit

WRITE key. The write command is synchronized to the display sweep with a D-flip-flop (second half 74HC74). In this way one or more whole sweeps are written to the memory regardless of the WRITE-key contact bouncing. The WRITE command enables the /WR clock. The latter remains in its inactive (high) state when writing is not enabled.

The digital memory requires an analogue interface as shown in Fig.4. The latter is used to adjust the A/D and D/A signal levels to the values used between the spectrum analyser and oscilloscope display (20dB/V, impedance 680Ω). Further, the analogue interface includes a circuit with operational amplifiers to compute the difference between the direct video signal and memory content.

The analogue interface includes a quad operational amplifier MC33074. The first op-amp (pins 5,6,7) is a voltage follower for the input signal. The A/D converter gets part of this signal through a resistive divider. The second op-amp (pins (8,9,10) amplifies the output of the D/A converter to the same level as available directly from the spectrum analyser. The third op-amp computes the signal difference. Finally, the fourth op-amp (pins-1, 2, & 3) operates as a voltage follower for the DIFFERENCE-OFFSET control voltage.

The four operational amplifiers run on a +12V supply, since the input and output video-signal voltages usually range between 1V and 6V. A stable +7V reference voltage is provided by the uA723 regulator. On the other hand, the A/D and D/A converters as well as the memory require a +5V supply voltage. The overall power supply is shown on Fig.5 providing +5V for the digital memory +12V for the analogue interface.

3. Storage Normaliser Assembly and Alignment

The wiring of the storage-normaliser modules is shown in Fig.6. The spectrum analyser provides four signals: video (Y-deflection), triggering (TRIG), blanking (BLANK) and saw tooth (X-deflection). The storage-normaliser only affects two signals: the video signal is being processed while the TRIG signal is used for synchronization of the address counter.

The storage-normaliser is built on two printed-circuit boards except for the power supply from Fig.5. The latter is built around the 7805 regulator and +12V supply connector. The digital part of the storage-normaliser (A/D and D/A converters, memory and clock/address generator) are built on a double-sided printed-circuit board with the dimensions of 120 mm x 80 mm as shown on Fig.7. The analogue interface is built on a single-sided printed-circuit board with the dimensions of 80 mm x 40 mm as shown in Fig.8. Both circuit boards are etched on 1.mm-thick glass fibre epoxy laminate FR4.

The storage-normaliser module location is shown on Fig.9. The storage-normaliser has the same depth (240 mm) as the spectrum analyser [1] or [2]. The width is 100 mm while the height is only 32

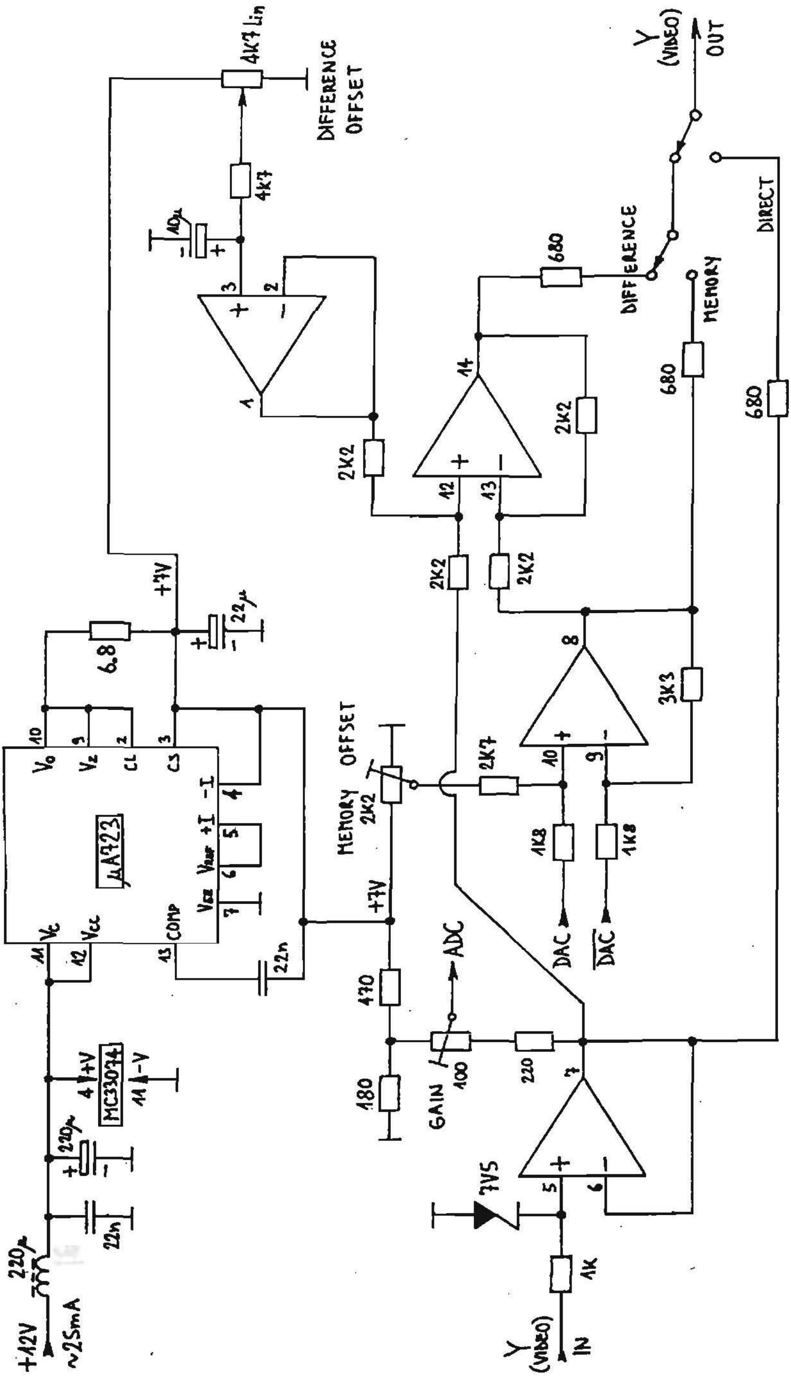

Fig.4: Analogue Interface

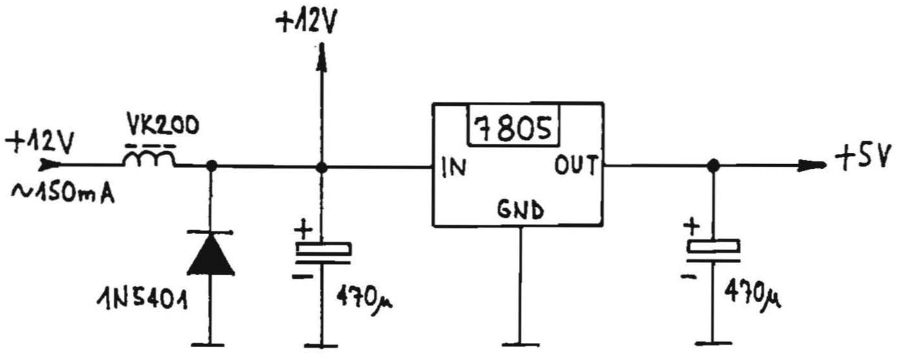

Fig.5: Power supply

mm, since all modules are located in a single plane. The bottom of the box is simply a piece of 1mm thick aluminium sheet, bent in the form of an "U". The cover is a similar "U" made from 0.6 mm thick aluminium sheet.

The 7805 regulator is bolted to the bottom plate for heat sinking purposes. The two 470μF electrolytic capacitors, VK200 RF choke and 1N5401 diode are simply soldered between the +12V supply connector and the leads of the 7805

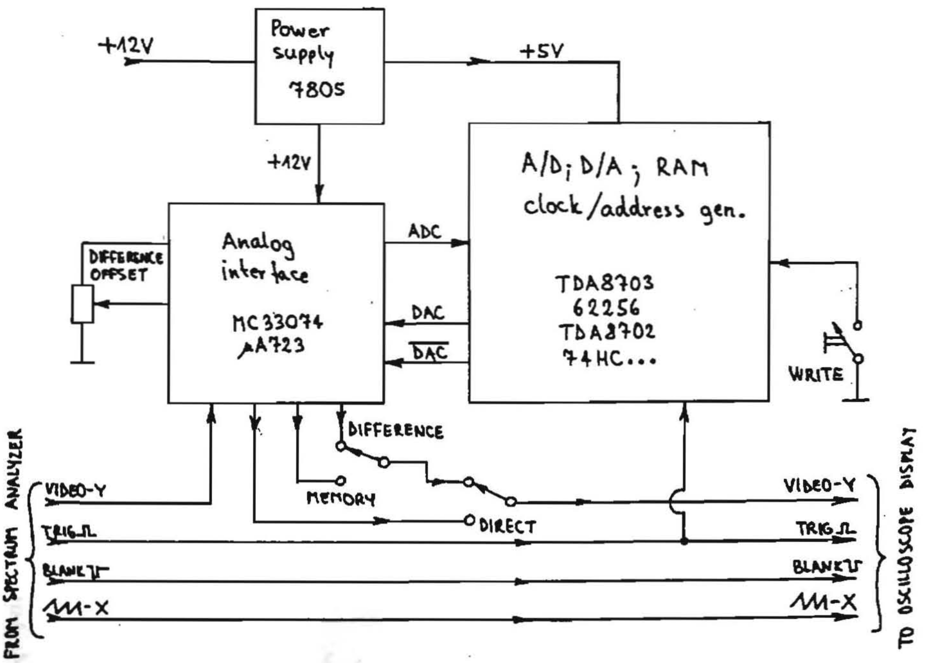

Fig.6: Storage Normaliser Wiring diagram

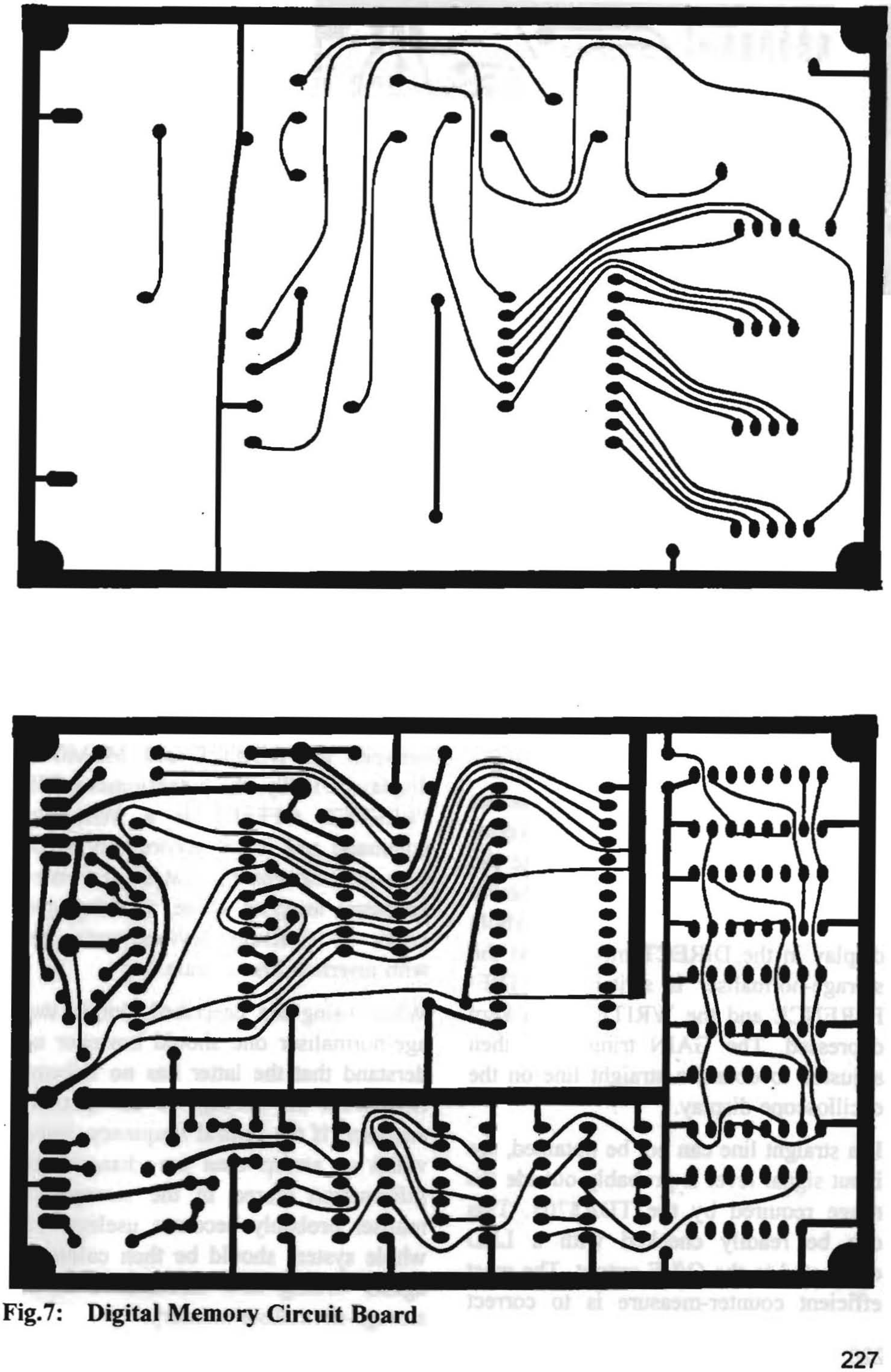

Fig.7: **Digital Memory Circuit Board**

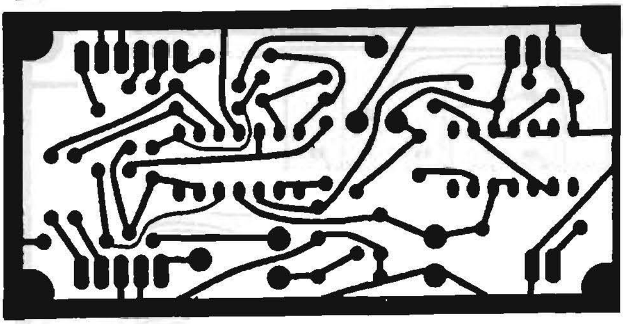

Fig.8: Analogue Interface Circuit Board

regulator. The overall current drain amounts to about 150mA.

Although the storage-normaliser is a low-frequency video circuit, the analogue interface requires a few alignments to make best use of the available dynamic range of both A/D and D/A converters. Of course the storage-normaliser should perform some useful function without any alignment (with both trimmers and potentiometer in central position) and this can be checked immediately with the oscilloscope display.

In the storage-normaliser the correct input signal level to the A/D converter should be set first. For this purpose the spectrum analyser is tuned to represent a wide and high peak across the whole display in the DIRECT mode. Next the storage-normaliser is switched to DIFFERENCE and the WRITE key is kept depressed. The GAIN trimmer is then adjusted to obtain a straight line on the oscilloscope display.

If a straight line can not be obtained, the input signal level is probably outside the range required by the TDA8703. This can be readily checked with a LED connected to the O/UF output. The most efficient counter-measure is to correct the DC offset of the video amplifier inside the spectrum analyser. Since the LED is no longer required after the video signal levels in the spectrum analyser and storage-normaliser are adjusted correctly, the LED is not installed on the front panel.

After the trimmer GAIN is adjusted correctly, the storage normaliser is switched alternatively in the DIRECT and MEMORY modes. The trimmer MEMORY OFFSET is then adjusted so that there is no observable difference between the DIRECT and MEMORY displays. Finally, the potentiometer DIFFERENCE OFFSET is a front-panel command and is set accordingly to the type of measurement that is performed: spectrum analyser alone, tracking generator or different devices under test with insertion loss or gain.

While using the described simple storage-normaliser one should however understand that the latter has no information about the settings of the spectrum analyser. If the central frequency, sweep width or sweep time are changed, the information stored in the storage-normaliser probably becomes useless. The whole system should be then calibrated again, writing new information in the storage-normaliser memory.

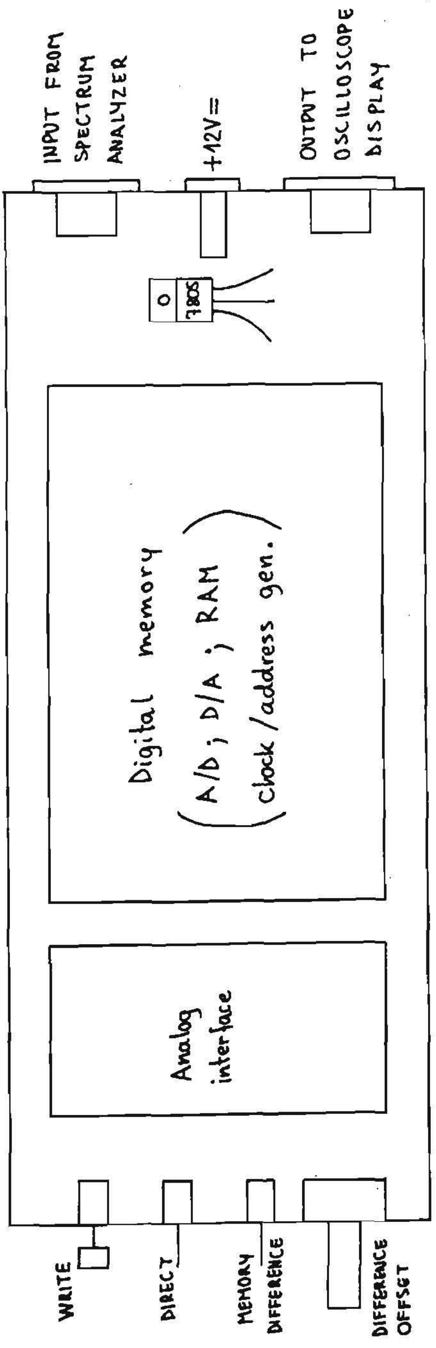

Fig.9: Storage Normaliser module Location

4. References:

[1] Matjaz Vidmar: 'Spectrum analyser 0...1750MHz', pages 2-30/1-99, VHF-Communications.

[2] Matjaz Vidmar: 'Spektrum-analyzer 0...1750MHz', to be published in AMSAT-DL Journal.

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Marker Counter for Spectrum Analysers

1. Amplitude and Frequency Display

Spectrum analysers are used to measure the frequency and amplitude of radio-frequency signals. Both quantities are at least roughly displayed on the CRT screen. When the spectrum analyser only sweeps across a narrow frequency band, some additional frequency information is required to locate the narrow segment in the whole frequency range covered by the spectrum analyser. Since the most popular amplitude display is 10dB/div, some additional accuracy is highly desired at least in a few interesting points on the CRT screen.

Older spectrum analysers were equipped with a mechanical frequency dial. The dial accuracy was limited by the precision potentiometer used to set the current through the tuning coil of the YIG oscillator. The YIG-oscillator frequency is exactly proportional to the DC magnetic field, set by the current through the tuning coil.

The delicate and unreliable mechanical dial was quickly replaced by a digital milliameter with three or four digits. The accuracy of this kind of frequency display is severely limited by the hysteresis of the core of the YIG magnet. It is sufficient to tune the spectrum analyser first to zero, then move to the highest frequency and return back to zero to observe frequency errors as large as +/-20MHz!

An accurate frequency display only became possible recently with the availability of true microwave synthesizers including microwave prescalers. There are still many new spectrum analysers on the market, including models with microprocessor control that do not have a true frequency readout. Since only the current through the tuning coil is measured, their frequency readout relies on the linearity of the YIG tuning response.

All spectrum analysers can be equipped with an external frequency counter. Since the circuit of a spectrum analyser includes many frequency conversions, the frequencies of all local oscillators have to be measured and the result

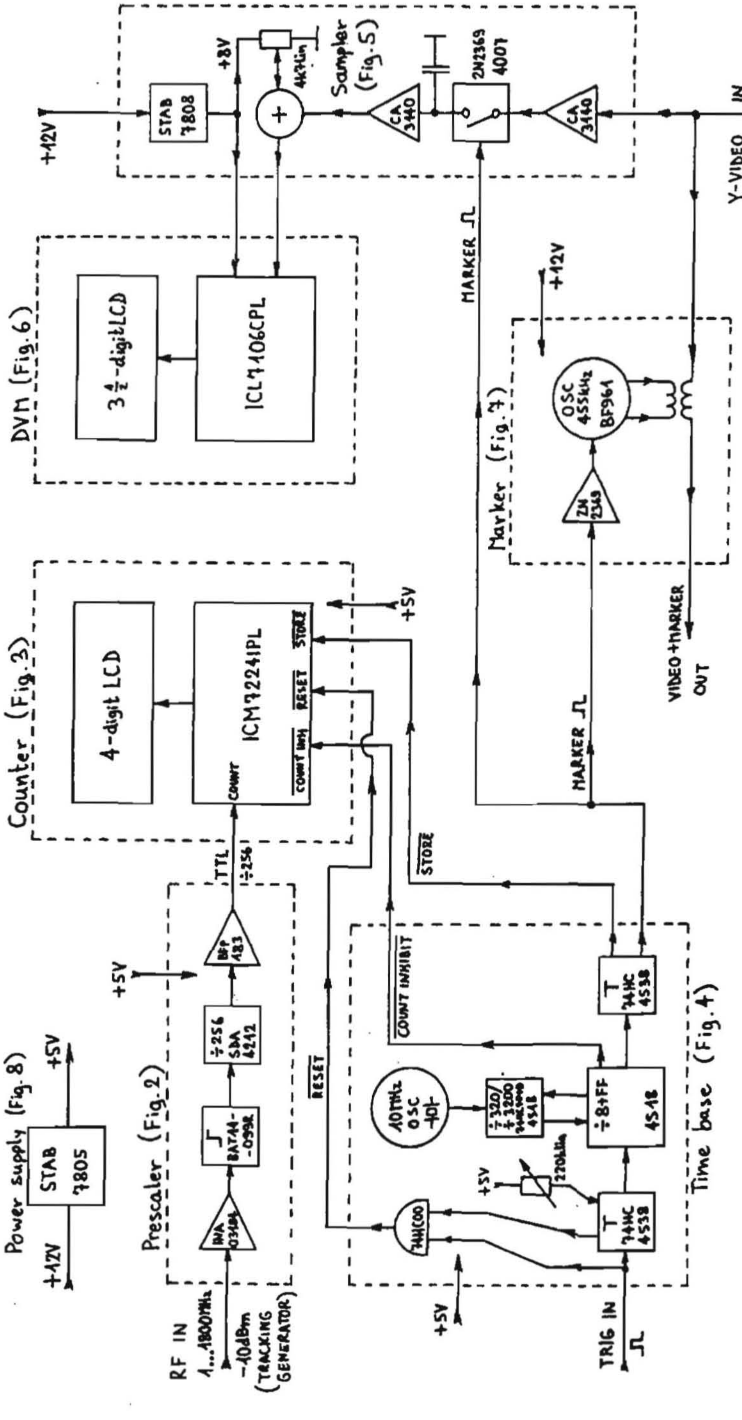


Fig.1: Marker Counter for Spectrum Analysers

added to or subtracted from the last IF value. Further, the gates of the frequency counters need to be synchronized with the spectrum-analyser sweep to measure the frequencies in a known point of the display.

The task of the frequency counter can be simplified with a tracking generator. The latter performs all required frequency summations and/or subtractions to obtain a signal on the exact frequency of operation of the spectrum analyser. While using a tracking generator, the operating frequency of the spectrum analyser can be measured with any frequency counter, provided that the spectrum analyser is switched to zero span.

Modern spectrum analysers with microcomputer-supported graphical displays can measure and display the frequency of one or more arbitrary points on the screen. These points are highlighted by well-visible markers on the screen. The frequency and amplitude of the signal at each marker are then displayed in numerical format as well.

The design of a suitable frequency counter displaying both frequencies and amplitudes of all markers allows many degrees of freedom and is almost independent on the type of the basic spectrum analyser as well as auxiliary equipment (tracking generator, storage-normaliser). For a single marker frequency measurement, a counter synchronized to the spectrum-analyser sweep is sufficient.

On the other extreme, a microcomputer-supported display is only limited by the performance of the microprocessor used to draw the picture.

A simple marker counter will be described in this article, designed to operate together with the spectrum analyser [1] or [2] and corresponding tracking generator [3]. The tracking generator allows a simple frequency counter with a single input and a single prescaler. Of course, the gate of the counter is synchronized to the spectrum-analyser sweep.

The block diagram of the marker counter for spectrum analysers is shown in Fig.1. The circuit performs three functions: in the selected point on the screen it measures and numerically displays the frequency and amplitude of the signal and at the same time draws a marker on the oscilloscope display.

The frequency counter includes three units: prescaler, counter and time base. The prescaler divides the input frequency by 256, allowing the use of a relatively slow counter. The counter module includes a decoder and driver for the four-digit, 7-segment LCD. The time base module provides a reset to the counter, opens the gate and stores the result for the LCD decoder/driver. A variable delay of the TRIG pulse coming from the spectrum analyser selects the horizontal position of the marker where all measurements are done.

The video-signal sampler is triggered at the same time as the frequency counter. The video-voltage sample is stored in a capacitor and displayed on a digital voltmeter. The scale of the latter is calibrated directly in decibels. An additional front-panel command allows an arbitrary offset of the decibel scale.

Finally, the same MARKER pulse drives the circuit that actually adds the marker to the video signal. The marker module includes a 455 kHz oscillator. The output of the latter is added to the Y-VIDEO signal, adding a short vertical line at the marker position on the oscilloscope display

Since spectrum analysers are sensitive radio receivers, the marker counter is installed in its own shielded case. Metal shielding is sufficient in most cases, even with a short whip antenna installed directly on the input connector of the spectrum analyser. Of course, if interference from the marker counter or tracking generator is suspected, either or both can be simply turned off. The circuits of the marker counter are therefore designed not to disturb the Y-VIDEO and TRIG signals in the power-off state.

2. Prescaler

The tracking-generator output frequency ranges almost from DC up to a few GHz. A high-speed prescaler is required to measure very high frequencies. On the other hand, a prescaler slows down the operation of the counter. Therefore, the divider modulo of the prescaler is not arbitrary.

In the case of a spectrum analyser, there is not much time to measure the frequency. The frequency measurement should be shorter than the time of one complete sweep, usually around 20 ms. The resolution of the frequency counter is therefore limited to 100 kHz. The latter requires 2.56 ms when using a divide-by-256 prescaler. A better frequency resolution could only be obtained by averaging several measurements in consecutive sweeps of the spectrum analyser.

An additional difficulty is represented by the zero on the frequency scale. The operation of the tracking generator is quite uncertain at very low frequencies. The prescaler is even less reliable at very low input frequencies. Accurate frequency measurements around zero can only be obtained by measuring the frequencies of all variable oscillators in the spectrum analyser and then computing the final result according to the conversions used in the spectrum analyser.

The lower frequency limit for the tracking generator shown in [3] is about 100 kHz. The latter is a very low frequency for ECL prescalers. Inexpensive prescalers for TV receivers are only designed to operate above about 70 MHz. The extension of the prescaler frequency range to very low frequencies requires careful input signal processing.

Inexpensive prescalers U664 and U891 were first tried in the described circuit. Their upper frequency limit is about 1.6 GHz and is very sensitive to chip tolerances and ambient temperature. It can be somewhat improved using a higher-than-nominal supply voltage. Unfortunately both the U664 and U891 will hardly operate correctly below 20 MHz, probably due to some capacitive coupling inside the prescaler chip itself.

Fortunately prescalers from other manufacturers did not show the same behaviour at very low input frequencies. Much better results were obtained with the

SDA4212. The latter operates up to 1.8 GHz at room temperature. On the other hand, its lower frequency limit can be extended to less than 1 MHz with suitable input signal processing. Both limits compare favourably with the requirements of the spectrum analyser described in [1] or [2].

The circuit diagram of the whole prescaler is shown in Fig.2. The input amplifier INA03184 is mainly required at low frequencies to transform the input sine wave into a square wave for the ECL prescaler. Even more important is the limiter with the BAT14-099R Schottky quad. The latter both shapes the signal and prevents saturating the input of the SDA4212.

The SDA4212 prescaler has a standard pin-out. The U891 could be used in the same socket, except for limiting the frequency coverage from 20 MHz to 1.6 GHz. The output signal of the ECL prescaler is amplified by the BFP183 transistor to TTL logic levels.

Most ECL prescalers allow some selection of the divider modulo with pin 5. A divider modulo of 256 was selected since it is available in most prescalers. Dividing by 256 provides an output frequency up to 7 MHz at an input of 1.8GHz. Since the following counter allows input frequencies up to 16MHz, the same circuit could directly count both VCO frequencies with faster prescalers like the uPB1505.

The prescaler module requires a single supply voltage +5V. All components are SMD types except for the SDA4212. Experiments have shown that the SDA4212 operates better while inserted in a good-quality IC socket rather than

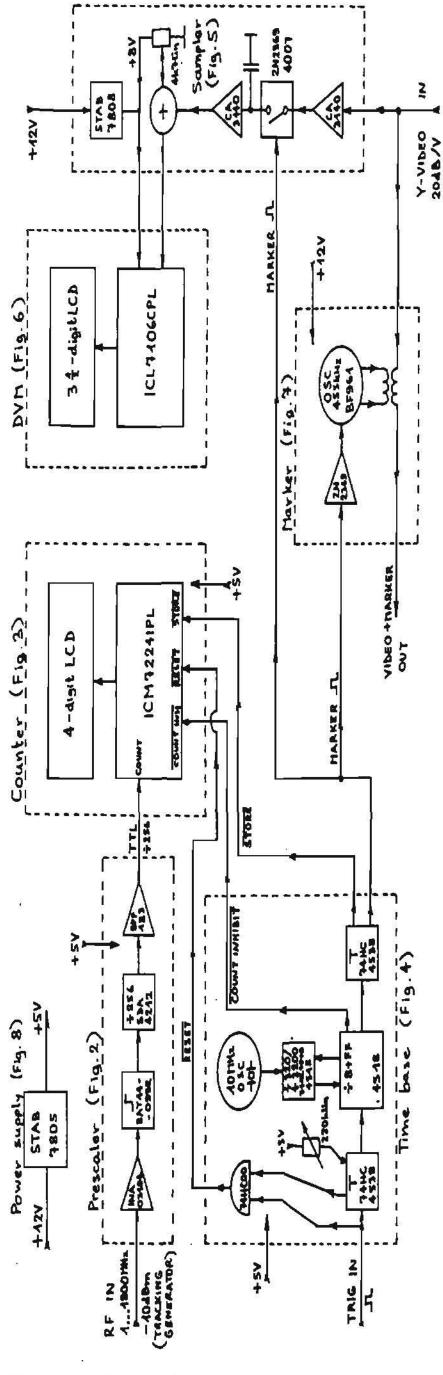


Fig.2: Prescaler

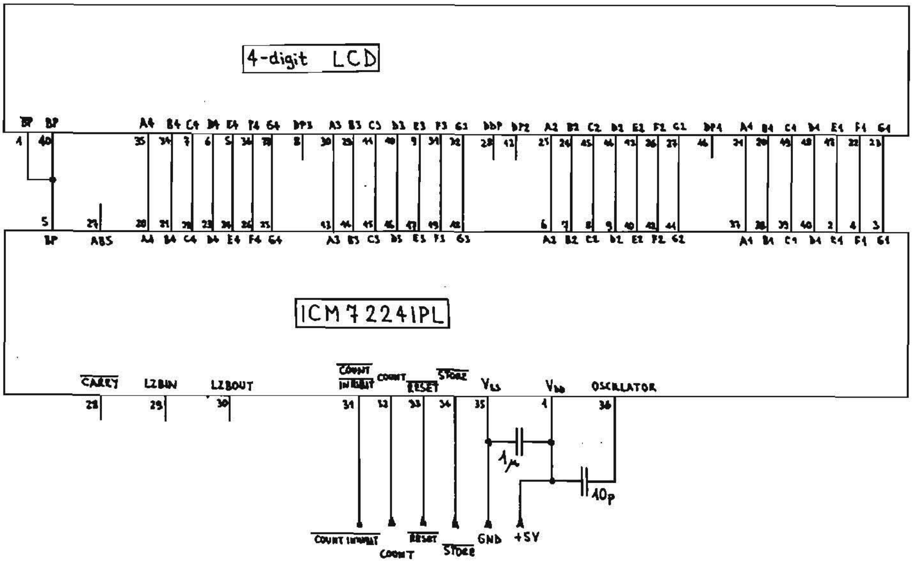


Fig.3: Counter

being soldered directly to the circuit board. It seems that the socket contacts provide some additional impedance matching for the SDA4212.

3. Counter

A digital counter is the most obvious component of a digital frequency meter. Of course the content of the counter has to be memorized and displayed at the end. Most frequency counters are equipped with 7-segment LED displays. The latter have a large current consumption leading to generation of large amounts of heat and radio-frequency interference. Both of the latter are highly undesirable in a sensitive piece of test equipment like a spectrum analyser.

On the other hand, liquid-crystal displays have a low power drain and generate little radio-frequency interference. Multiplexed LCD modules with integrated drivers and controller are certainly the easiest to use. Unfortunately, due to the LCD multiplexing, their contrast is poor and it is relatively difficult to get such displays with large characters.

The described frequency counter is therefore designed around an unmultiplexed LCD with four large digits as used in table clocks. A suitable counter, memory, 7-segment decoder and LCD driver is available in a single integrated circuit ICM7224IPL. With the latter, a number of 40xx or 74HCxxx integrated circuits or a programmed microcontroller are no longer necessary.

The connection of the ICM7224IPL is

shown in Fig.3. The counter section is controlled through the inputs COUNT and /COUNT-INHIBIT. The COUNT input is driven by the prescaler. The /COUNT-INHIBIT input enables or stops the counter. On the other hand, any level transitions on the /COUNT-INHIBIT input will not advance the counter inside the ICM7224IPL as long as the COUNT input does not toggle. The content of the counter is copied to the memory with a low pulse on /STROBE. Finally, the counter is reset to zero with a low pulse on /RESET.

Since the LCD is not multiplexed, each segment on the display requires its own connection to the ICM7224IPL. The latter is also driving the back plane (BP) electrode common to all segments. In this way the display driver always applies an alternate voltage of a few tens or hundreds Hz to the LCD.

The LCD frequency is provided by an internal oscillator inside the ICM7224 IPL.

The ICM7224IPL and the LCD have a few unconnected pins, like the decimal points of the LCD. The ICM7224IPL could even drive a fifth digit (segment AB5) that is not available in the LCD used in this project. On the other hand, the /CARRY output allows the concatenation of several ICM7224IPL and corresponding displays. The LZBIN input and LZBOUT output allow correct leading-zero blanking when several ICM7224IPLs are concatenated. In the described circuit the LZBIN input is not connected, since it is kept in the correct logic state by an internal resistor.

The ICM7224IPL requires a single supply voltage +5V. At +5V supply the counter section is able to operate correctly up to 15...25MHz. In order to save space on the front panel of the marker counter, the ICM7224IPL is installed below the LCD. The single-sided printed-circuit board requires two jumpers (Vdd and BP) below the ICM7224IPL.

4. Timebase

Since the marker counter has to be synchronized to the spectrum-analyser sweep, the design of its time base slightly differs from conventional frequency counters. Besides the synchronization with the spectrum analyser, the time required by the frequency measurement itself should be considered. If the spectrum-analyser sweep is reasonably linear, the counter measurement will correspond to the frequency in the centre of the measurement interval.

Besides steering the counter gate, memory and reset, the time base also provides MARKER pulses to other circuits to sample the video signal and draw a marker on the corresponding point on the screen. Of course the MARKER pulse should be generated exactly in the centre of the counter gate pulse fed to /COUNT-INHIBIT. The circuit diagram of the time base is shown in Fig.4. The TRIG pulse from the spectrum analyser resets the counter and triggers the first monostable (first half of first 74HC4538). The latter produces a variable delay to adjust the

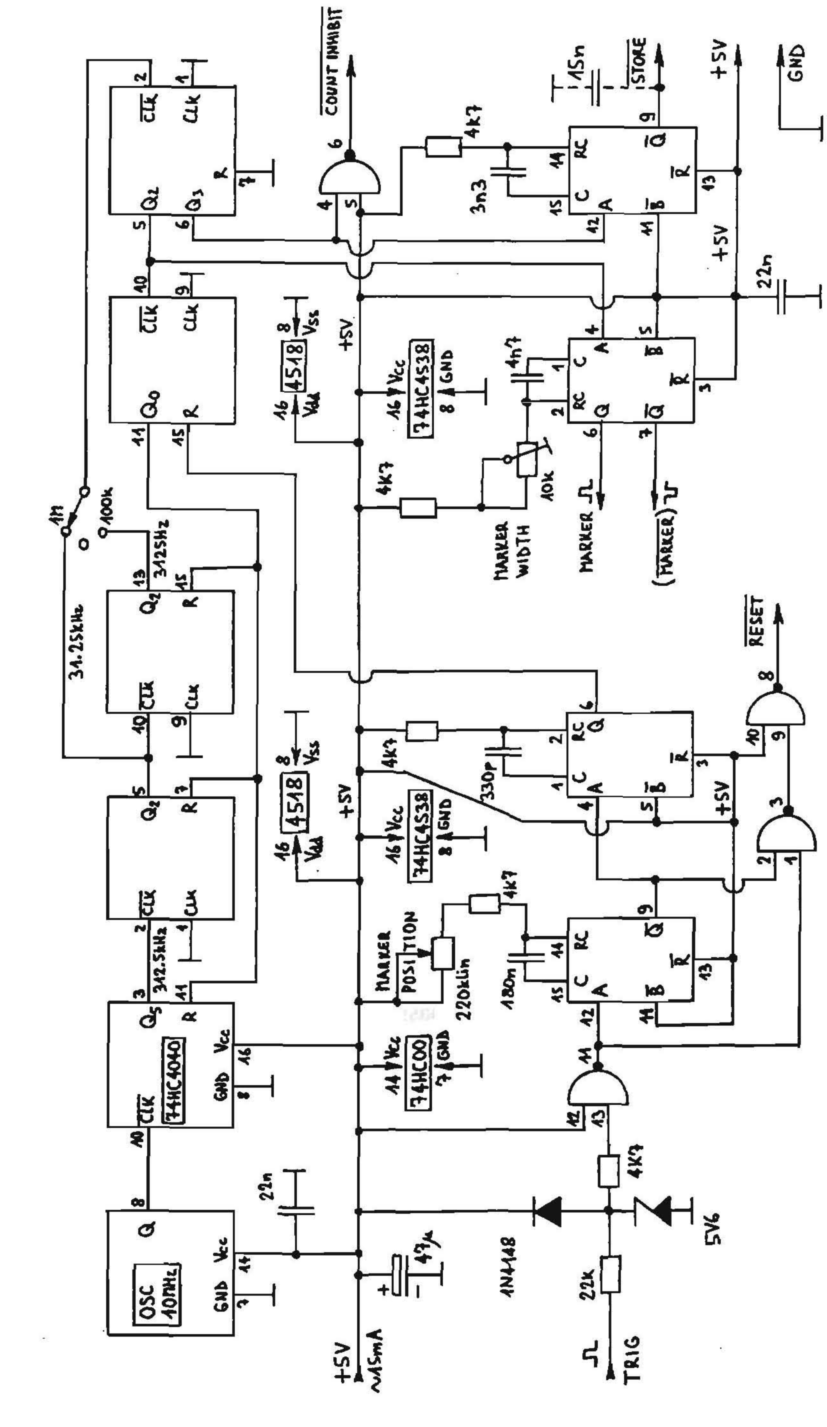


Fig.4: Timebase

marker position. After the first monostable times out, the second half of the same 74HC4538 produces a microsecond pulse.

The microsecond pulse starts the time base by resetting the flip-flop in the second 4518 (pins 10, 11 and 15). The flip-flop releases the time-base divider including a 74HC4040 and another 4518, driven by a 10 MHz crystal oscillator. The divider produces either 31.25 kHz or 3125 Hz according to the desired counter gate time for 1 MHz or 100 kHz resolution. The decade counter in the second 4518 (pins-2, 5 and 6) waits in the state "8". The incoming clock will move the decade counter to 9, 0, 1, 2, 3, 4, 5, 6, 7 and back to 8. When the state "8" is reached, the flip-flop is triggered and the time-base divider is blocked. The output /COUNT-INHIBIT is enabled between states 0 and 7 for a total of 8 clock periods or 256us (resolution 1MHz) or 2.56ms (resolution 100kHz). After the counter gate is closed, a ten microsecond pulse /STORE is generated to copy the counter content in the display memory (second half of second 74HC4538).

In the middle of the counter-gate period, on the transition from state 3 to state 4 of the decade counter, the first half of the second 74HC4538 is triggered to produce the MARKER pulse. The MARKER pulse width is set to about 30 microseconds to produce a well-visible marker on the oscilloscope screen as well as drive the video-signal sampler.

The time base requires a single supply voltage +5V. The latter also requires a wire jumper under the second 74HC4538 on the single-sided printed-circuit board. All control signals for the counter (/RESTE, /COUNT-INHIBIT and /STORE) are available on a single connector including +5V and ground. The TRIG input is protected with diodes and resistors also in the case when the marker counter is powered off.

5. Sampler

While the amplitudes of all displayed signals can be read easily from the spectrum-analyser screen, an additional digital display of the signal amplitude at the marker position is always welcome. The spectrum analyser presented in [1] or [2] has an analogue Y-VIDEO output providing 20dB/V. Of course the Y-VIDEO output changes a lot during a single sweep across the screen. To measure the signal level at the marker position, the Y-VIDEO signal has to be sampled at the appropriate point in time.

The circuit diagram of the video-signal sampler is shown in Fig.5. The video signal is first fed through a simple low pass (22kΩ, 68pF) to the voltage follower with the first CA3140 op-amp. The CA3140 avoids loading the video-signal line in all cases: when the sampler is operating and in the power-off condition. The 7V5 Zener diode is used to protect the MOS input of the CA3140.

The sampler includes a transmission gate (built with the MOS transistors contained in the 4007) and a 33nF capacitor. The CMOS transmission gate

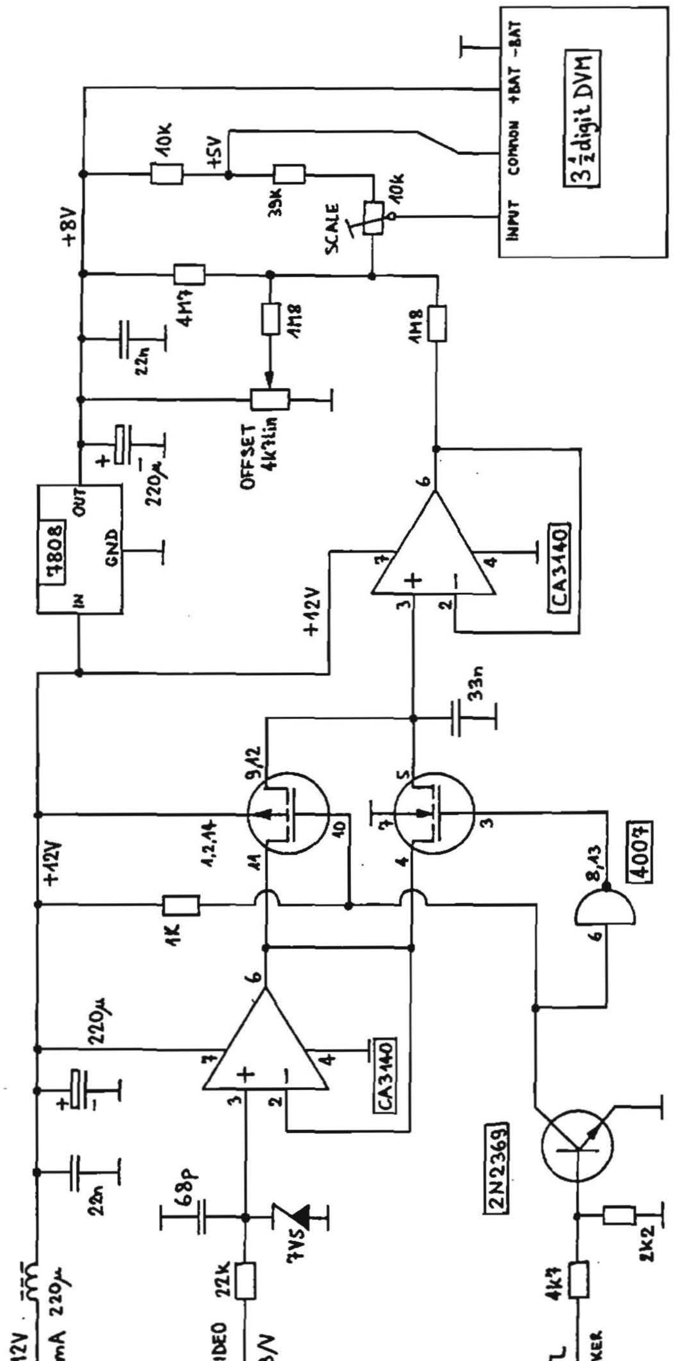


Fig.5: Sampler

is turned on only for a very short period by the MARKER pulse, amplified by the 2N2369 transistor to CMOS logical levels. The 33nF capacitor then holds the sampled voltage, followed by another MOS voltage follower with the second CA3140 op-amp.

The CA3140 operational amplifiers have many desirable features. Besides a very high impedance of the MOS inputs, their input and output voltage ranges go down to the negative supply rail. The latter feature allows a single positive supply +12V for the op-amps. The CA3140 also withstands large overloads on the inputs, up to +8V above the positive supply rail. The latter prevents damage to the op-amp in the power-off condition.

The 4007 was selected as the sampling switch because of repeatability. More common CMOS transmission gates like the 4016 or 4066 may have very different electrical performances when supplied by different manufacturers.

The output voltage can be displayed in many different ways. The simplest solution is to use a digital-voltmeter (DVM) module with a similar non-multiplexed LCD as used in the frequency counter. While DVM modules are cheap and easily available, the corresponding user manual usually requires to have the power supply isolated from the measured voltage.

The requirement for the isolated supply for the DVM module can be overcome easily by studying the internal circuit diagram of the DVM. Most DVM modules with a 3-1/2 digit LCD are built around the integrated circuit ICL7106CPL as shown in Fig.6, including those with an unmarked, bare chip bonded directly to the printed-circuit board. Some additional components may be included in some DVM modules to drive the decimal points on the display.

The nominal DVM-module supply voltage is a 9V battery connected between +BAT and -BAT. Internally the ICL7106CPL includes a precision regulator for the 2.8V reference voltage between +BAT and COMMON. Besides being used as a source for the reference voltage between REFLO and REFHI, the regulator also provides a virtual ground called COMMON for all the analogue circuits inside the ICL7106IPL. One of the voltmeter inputs (usually INLO) is connected directly to COMMON already inside the DVM module.

The sampler circuit board includes a 7808 regulator to supply the DVM module with +8V on +BAT, while -BAT is connected to ground. In this case COMMON is held at about +5.2V. While designing additional circuits around the DVM module, one should consider that the internal regulator inside the ICL7106CPL can only sink current from COMMON (load between COMMON and +BAT).

DVM modules are usually designed for a full-scale sensitivity of +/-200 mV. A resistive voltage divider is required to measure higher voltages, so that the voltage between INPUT and COMMON remains within the +/-200mV range. If the resistive divider pulls current from COMMON, then an additional load from COMMON to +BAT is required, like the 10kΩ resistor in Fig.5, to prevent any current being sourced from COMMON.

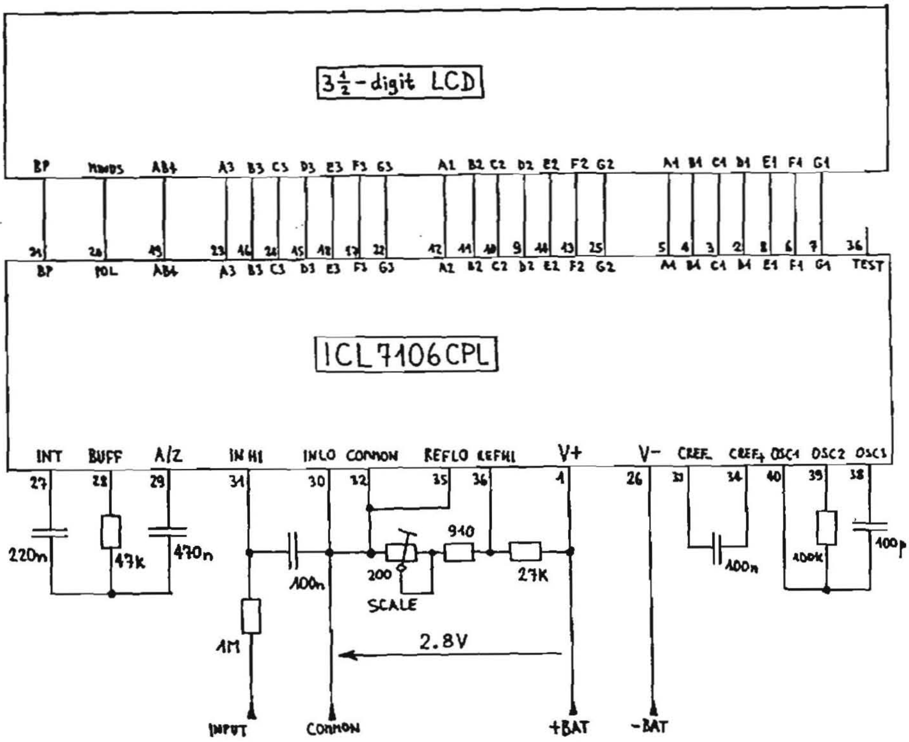


Fig.6: DVM

Since the Y-VIDEO signal is logarithmic 20dB/V, it makes sense to calibrate the DVM scale directly in dB (or tenths of dB). A 0.1dB change in the signal level is represented by a 5mV change in the Y-VIDEO signal. The latter should be divided by 50 to match the DVM steps of 0.1mV (3-1/2 digit full scale +/-200mV). The exact divider ratio is set by the 10kohm trimmer SCALE. The front-panel command OFFSET allows adding an arbitrary offset to the sampled Y-VIDEO value.

The sampler requires an unstabilised supply of +12V for both CA3140s and the 4007. The DVM and OFFSET potentiometer are supplied by the 7808 regulator. The Y-VIDEO input is designed to represent a high-impedance load both during power on and power off.

6. Marker

Numerical frequency and amplitude displays are of little value if it is not known to which signal they refer to. The simplest way to indicate the measured signal is to draw a well-visible marker in the corresponding place on the spec-

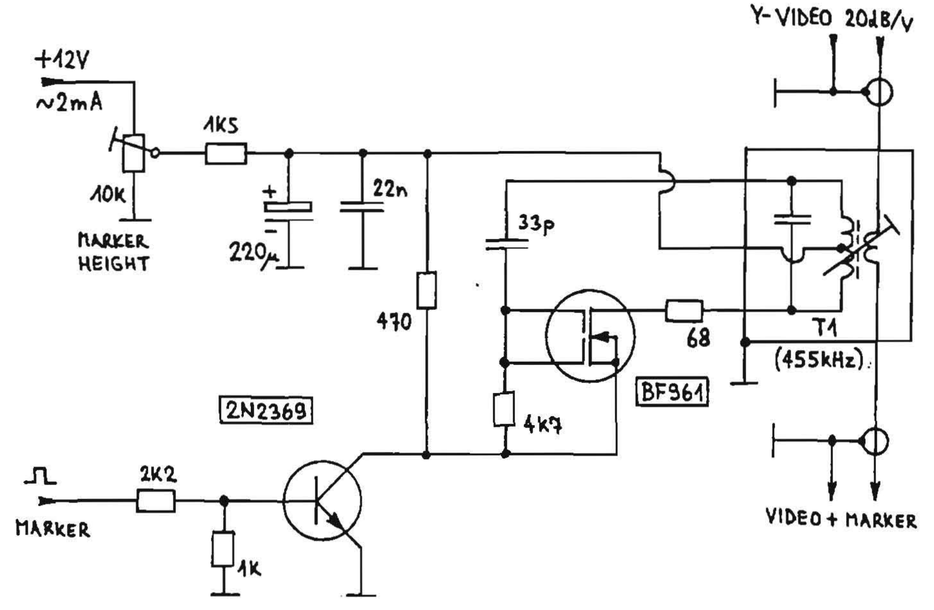


Fig.7: Marker

trum-analyser display. The marker can be drawn in many different ways depending on the accessible signals driving the cathode-ray tube or other display device: vertical (Y) deflection only, both vertical and horizontal (XY) deflection and/or beam intensity (Z).

In the most general case only the vertical (Y) deflection is available. The marker pattern should therefore be added to the Y-VIDEO signal. Of course the marker pattern should be selected in such a way that it is not confused with the typical patterns displayed by the spectrum analyser. At the same time, the marker pattern should not corrupt much of the information contained in the Y-VIDEO signal.

The marker circuit shown in Fig.7 generates a short vertical line as the marker pattern. The latter extends both above and below the actual trace generated by the spectrum analyser. The line pattern is generated by adding a few oscillations of a sine wave 455 kHz oscillator to the Y-VIDEO signal.

The 455 kHz oscillator includes a BF961 MOS transistor as the active device and an IF transformer (white core or AM2) as the selective feedback. The MOS transistor allows both a fast start-up of the oscillator as well as a fast shutdown after the power is removed. The 470 resistor across the oscillator supply speeds up the shutdown.

The oscillator output is added to the Y-VIDEO signal through the secondary winding of the IF transformer. The circuit is designed to obtain a pattern height of about one division or 0.5Vpp while using a standard IF transformer for 455 kHz. When the marker circuit is

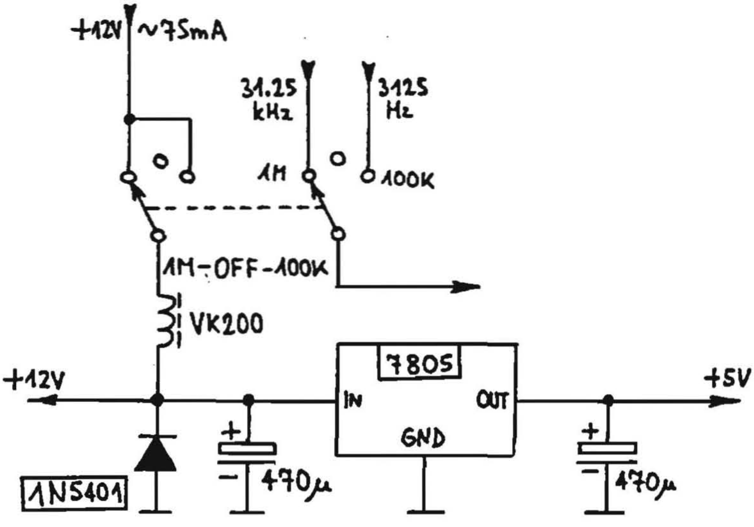


Fig.8: Power Supply

powered off, the 470Ω resistor loads the primary of the IF transformer so that the circuit has no effect on the Y-VIDEO signal..

The oscillator is turned on or off by the 2N2369 transistor. The marker pattern height is set by the supply voltage with the 10kohm trimmer. Since the duty cycle of the oscillator operation is very low, its supply current comes from the 220µF capacitor. The latter is then slowly recharged through the rest of the cycle through the trimmer and 1.5kΩ resistor. Since the +12V supply is not stabilized, the marker height may change slightly with the supply voltage.

7. Assembly of the Marker Counter

The marker counter is built in the same way as the corresponding spectrum analyser [1] or [2] and tracking generator [3]. The +5V supply comes from a 7805 regulator as shown in Fig.8. To save some space on the front panel, a three-position switch is used to select the counter resolution (1 MHz or 100kHz) or to turn the marker counter off.

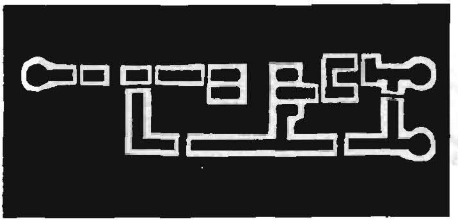


Fig.9: Prescaler PCB; 30 x 60mm

The marker counter includes a single RF printed-circuit board for the prescaler, built with SMD components and shielded in a box of 0.5 mm brass sheet with the dimensions of of 30 mm x 60 mm x 30 mm The oscillator output is added to the Y-VIDEO signal through the secondary winding of the IF transformer. The circuit is designed to obtain a pattern height of about one division or 0.5Vpp while using a standard IF transformer for 455 kHz. When the marker circuit is powered off, the 470ohm

resistor loads the primary of the IF transformer so that the circuit has no effect on the Y-VIDEO signal.60mmX30mm. The prescaler circuit board is shown in Fig.9 and is etched on single-sided, 0.8mm thick glass fibre epoxy laminate FR4.

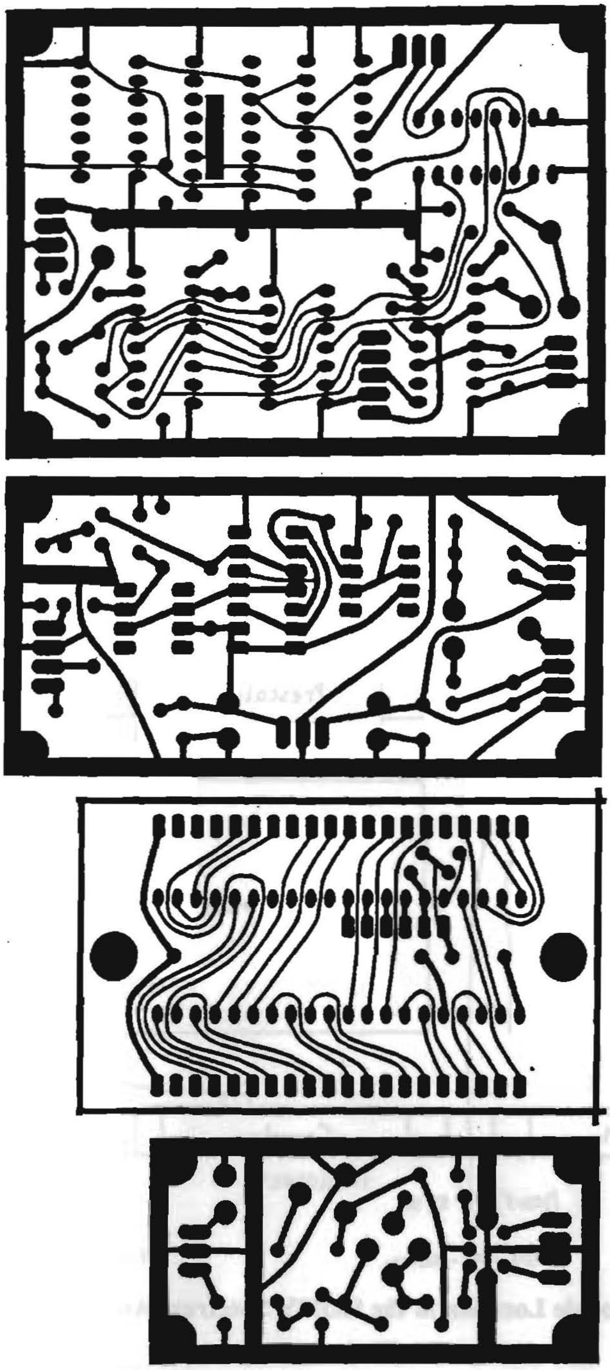
All other circuit boards only carry low-frequency circuits built with standard components with wire leads. The circuit boards are shown in Fig.10 and are all etched on single-sided, 1.6 mm thick glass fibre epoxy laminate FR4. The single-sided boards require a few wire jumpers: two jumpers under the ICM7224IPL in the counter module and one jumper under the second 74HC4538 in the time base. The DVM module is usually available already built, so no special circuit board is required.

The marker counter module location is shown in Fig.11. The marker counter has the same depth (240 mm) and width (220 mm) as the spectrum analyser [1] or [2]. The height is set to 42 mm by the available DVM module and counter LCD. The bottom of the box is simply a piece of 1 mm thick aluminium sheet, bent in the form of an "U". The cover is a similar "U" made from 0.6 mm thick aluminium sheet.

The 7805 regulator is bolted to the back plate for heat sinking purposes. The two 470uF electrolytic capacitors, VK200 RF choke and 1N5401 diode are simply soldered between the +12V supply connector and the leads of the 7805 regulator. The overall current drain amounts to about 80mA. The empty space in the box of the marker counter could be used for further additions like a computer interface.

The marker counter is a relatively simple piece of equipment that should operate without any tuning. Some settings are self evident, like the marker height and width. If no marker can be obtained, the tap on the primary of the IF transformer may be too far from the centre of the winding and the oscillator may not work at all.

The accuracy of the counter is defined by the 10 MHz crystal oscillator. While checking the frequency counter, both the lower and upper frequency limits have to be tested. If the frequency counter displays strange symbols on the LCD at particular counts, then a 15nF capacitor has to be added from /STORE to ground (see Fig.4).



Time Base

60 x 80mm

Sampler

40 x 80 mm

Counter

40 x 68 mm

Marker

30 x 60 mm

Fig.10: Other (Low-Frequency) Printed Circuit Boards

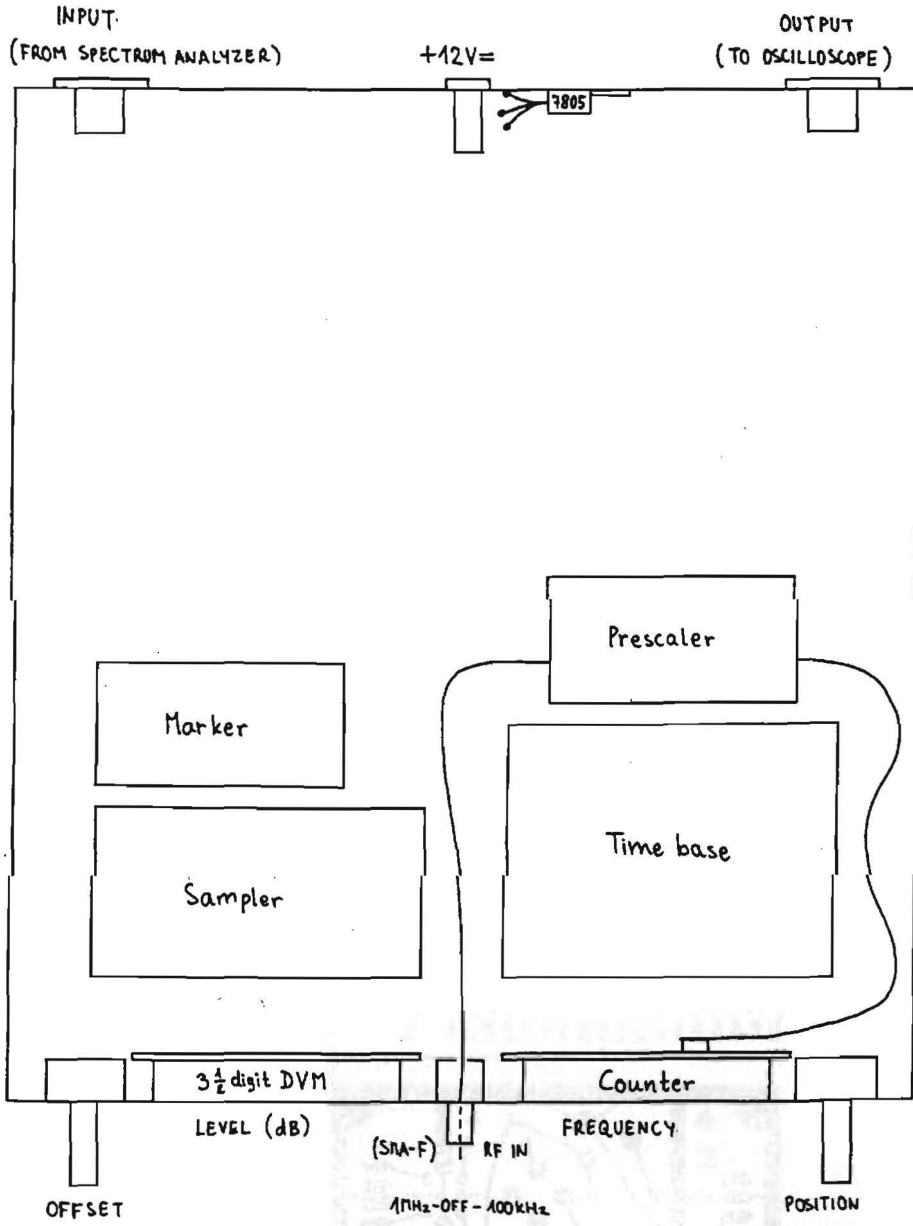


Fig.11: Marker Counter Module Location in the S53MV Spectrum Analyser

Finally, the scale of the DVM has to be set correctly so that the display is calibrated in decibels. The easiest way is to use the SCALE trimmer in the sampler module and a calibrated step attenuator between the tracking-generator RF output and spectrum-analyser RF input.

The connection of the decimal points of both LCD's may not be simple, since the active LCD segments should only receive an AC voltage. Any DC component might damage the LCD through electrolytic processes. Some cheap DVM modules have jumpers that connect the decimal points to the COMMON pin of the ICL7106CPL. Due to the lower amplitude, the contrast of the decimal points may not be as good as that of the regular seven segments. In a similar way, the decimal points of the counter display may be turned on by connecting them to ground through a suitable capacitor.

8. References

[1] Matjaz Vidmar: 'Spectrum analyser 0...1750MHz', VHF-Communications 1/99, pp 2-30

[2] Matjaz Vidmar: 'Spektrum-analyzer 0...1750MHz', to be published in AMSAT-DL Journal.

[3] Matjaz Vidmar: 'Tracking Generator for the Spectrum Analyser 100kHz to 1750MHz', VHF-Communications 2/99, pp. 66-79

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Duncan Head, G7PNE

Receive Amateur Television with this Low-Cost Conversion of a PACE PRD800 Satellite Receiver

Editor: this article first appeared in the BATC publication CQ-TV 188 and we thank the editor for permission to reproduce it here

The Pace PRD800 Satellite receivers can be converted easily and cheaply to give admirable results on the 23cm ATV bands. This article describes the conversion, complete with circuit diagrams and procedures. No special tools or alignment equipment is necessary, so anyone handy with a small soldering iron should manage this in a few hours.

Do not be fooled by the low-quality results often obtained by unsuitable ASTRA receivers. I.e. Amstrad, conversions of these are a waste of time and money. The Pace unit is a high-quality design.

The Pace model, selected with the help of Martin Pickering of Satcure, offers excellent video and audio demodulation, exhibits good low-noise characteristics and. most importantly, can be modified to provide voltage-controlled tuning.

The unit should be tested prior to dismantling, ideally connected to a satellite dish. This model, similar to most other receivers, has a standby mode be aware, however, that most components and power supplies remain fully operational in this mode. Always remove the mains plug prior to handling and soldering.

1. CONVERSION METHOD

Reset the memory to factory defaults prior to conversion by quickly pressing the appropriate keys on the control unit:

menu, P-/--, STORE, >right, <left

note that on some later "Plus" models press 0 instead of P)

Switch off the blue screen:

Press F, Store

Once the reset has been completed remove the mains plug and remove the main PCB. Note the small plastic retaining pins.

A small power (18W) soldering iron with a round tip and de-soldering braid is recommended for removal of the PCB components.

1.1 12V LNB Supply

The LNB supply is switched by Q2. Remove R467 (270Ω) or Q2, disabling the H/V polarisation signal fed to the coaxial cable (12-18V switching). This will give 12V only (13V nominal) into the coax for powering the ATV 23cm Low-Noise Amplifier, which should be mounted as close to the 23cm aerial as possible. The voltage can be adjusted to exactly 12V by adding an 1N4001 diode in series with D16 and it also is advisable to put a 250mA fuse into this supply and also add a switch maybe.

Do not connect an aerial direct to the satellite receiver. This will present a DC short to the receiver and damage the 12V supply components.

1.2 Video Response

Fit a 100pF capacitor across the tuner base band output at pin-11 to ground (pin-11 as counted on the PCB pads). It is also advisable to ground the RF Modulator case with a thick wire braid from one of the end ground tuner support pins. There may already be a 33pF capacitor on pin-11 connected to the +5V rail, if so this component should be removed.

1.3 Video Gain Control

The video circuit on this model has a clamp and sync-separator circuitry. This

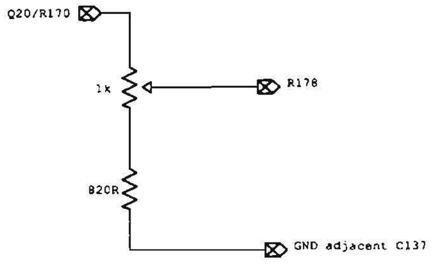

Fig.1: Video Gain Control

is not required in this application and as it caused excessive noise it is best bypassed.

Connect a screened cable from the junction of Q20 and R170 (680Ω) to a 1kΩ potentiometer (Fig.1). Connect the other side of the potentiometer to ground via an 820Ω resistor. Remove R177 (360Ω) and R178 (470Ω).

Connect the wiper of the potentiometer to the PCB junction of R177 and R178, again using miniature screened cable (RG174).

This signal is then fed via the graphics IC (U10) M50555, which adds the menu text, etc. This can be bypassed (or switched in/out) by removing R519 (0Ω link) and connecting the video signal direct to the test connection S10 on the other side of this link. The menu system was left permanently connected on the unit I use.

For SCART users, utilise the middle TV-OUT socket. If the signal is too large fit a 33Ω resistor between pins-19 and 20. The RF output from the on-board modulator is not affected by this SCART modification.

1.4 Tuning

The original PLL menu-driven tuning is de-activated in favour of manual voltage control..

Remove R128 (100 kΩ) adjacent to pin-13 of the tuner module.

The tuning range is band switched between ATV repeater input (1249 MHz) and outputs (1316-1318 MHz) by a rotary 2-pole/2-way switch. The supply is Zener stabilised to give optimum zero drift characteristics.

Install the simple circuit shown in Fig.2. The 9.1V Zener diode and the dividing resistors should be soldered to the back of the switch. With the standard tuner module the following voltages apply:

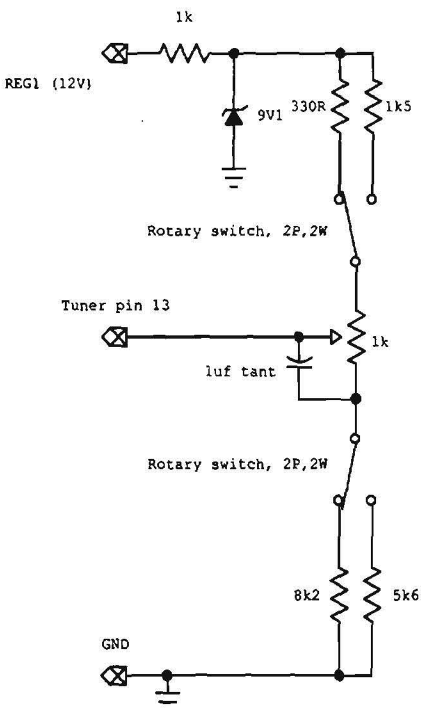

Fig.2: The Tuning Modifications

1249 MHz 6.4V
1318 MHz 8.4V

Fit both a 0.1μF ceramic and a 10μF tantalum capacitor across the tuner voltage control input pin-13 (tuner) to ground. This removes any noise.

If, on initial testing prior to modification, or after upgrading to the high-quality tuner, the picture quality is streaky or noisy, then the switched-mode power supply capacitors and coils may require replacing.

An upgrade kit RELKIT1, available from Satcure will remedy this. The following two capacitors (which are included as part of the RELKIT1) may be fitted instead. However, the upgrade kit will increase the long-term reliability of the whole unit and is thus highly recommended.

Fit a 1000μF 10V electrolytic capacitor across the 5V supply (pin-10 tuner) and ground. Install it on the underside of the PCB. Fit a 2200μF 10V electrolytic capacitor from L31, the 5V supply, to ground. Install on top of the PCB using the tuner body as the ground connection.

1.5 Audio

The audio circuit in the Pace series of satellite receivers is very sensitive indeed. Only minor modifications are required. The TDA6160 audio demodulator IC (U11) is, however, digitally controlled, but modifications allow manual voltage controlled tuning with a 1kΩ potentiometer.

Remove R192 (470Ω) adjacent to L16. Fit a 1kΩ resistor in its place to slightly narrow the bandwidth.

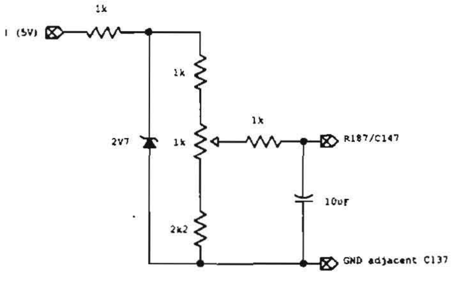

Fig.3: Audio Control Circuit

Remove R188 (10kΩ). Install the control circuit shown in Fig.3.

The original tuning voltage for the TDA6160 IC in this Pace model varies from 0.5 to 4.5 volts, which gives full coverage for all those different satellite audio frequencies. For ATV (UK specifications) at 6 MHZ app. 1.7 volts is required.

Fit a 4.7kΩ resistor across R24 (4.7kΩ) and a 15kΩ resistor across R212 (4.7kΩ) to increase the audio gain. Remove C169 and connect in its place a 4.7kΩ resistor and a 10nF capacitor wired in series. Fit a 10kΩ resistor and a 10µF 10V electrolytic capacitor wired in series across R214 (10kΩ).

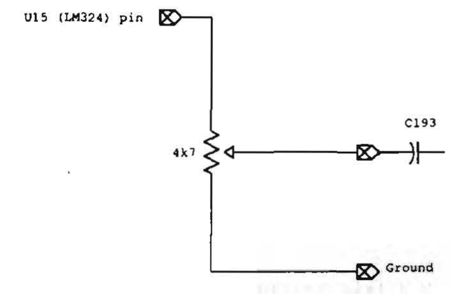

Fig.4: Optional Audio Amplifier

1.6 Audio Amplifier (optional)

Remove C193 and re-connect the negative lead back to the Q26 junction (the opposite way to before) on the PCB top side. Fit a 4.7Ω resistor across R262 (75Ω), a 220Ω resistor across R568 (220Ω) and an 18kΩ resistor across R258 (33 kΩ). Cut the PCB track from C195 (1000µF) negative side which goes to pin-19 of the VCR SCART socket. Connect an 8Ω loudspeaker (or route to a jack socket for external connection of desired) between C195 negative and ground. Install the control circuit shown in Fig.4

1.7 Decoder

Holding a test point high to +5V defeats the decoder circuit. Link TST2 test point to C309 positive via a 4.7kΩ resistor on the underside of the PCB.

1.8 Auto Power-Up

The standard unit powers up in standby mode. Connect a 100µF 10V capacitor, positive to R583 (82Ω) in the 5V supply circuit and negative to the standby PCB switch connection to auto power up. This is good for repeater mode, or where normal operation is required automatically after a power outage.

1.9 Mounting And Installation

The potentiometer and switch(s)can be mounted on the units plastic front panel. A more suitable new flat front panel rather than the curved one, suitable for this chassis, is available from Satcure and certainly offers more scope for mounting controls, etc.

2. TESTING

Power up the fully completed conversion and press either Channel 1 on the remote control, or the standby (on) button on the front panel. Adjust the tuning control potentiometer and check that the voltage range measured on the wiper is correct. On pressing "MENU" the blue screen should appear. Adjust the contrast (video gain) value found in the install menu, I found '7' to be a good value. Switch off the AFC (offset) found in the LNB set-up. Set the audio to mono and 50uS equalisation. The Panda setting sounded too dull. After these changes the remote control is not required for ATV operation, just press the standby button to power up and rotate your 23cm aerial and tune in to you local ATV repeater.

Note that the noise figure of the LNA, threshold value of the receiver, together with the quality of the coaxial cable and the aerial gain are the secret for successful ATV operation.

3. TWEAKS AND REFINEMENTS

Units with the standard tuner module: with the unit unpowered carefully compress the 2-turn coil (by 1mm) that can be just seen through the cut-out in the tuner cover. This has the effect of changing the broadband response slightly and peaks it lower down the band (1.3 GHz).

If you have a tuner with two pre-set trimmer potentiometers (again just seen below the cut-outs) then tune into a weak ATV signal with a few sparkles (P2 to P3 signal). Adjustment of the pre-set closest to the F-socket input connector may increase the signal quality by another P point. Take care not to short anything use an insulated/plastic trimming tool.

13. FINAL TESTS AND RESULTS

Once converted the unit was tested against an existing dedicated ATV receiver system. The results were extremely good, producing a reduction in noise and sparkles with a corresponding gain in P points by 1 or 2.

Further developments will be a drop-in replacement tuner module for this Pace unit, that boasts 15 MHz bandwidth and a lower threshold of only 4dB. The ultimate for ATV. This has been tested and found to give a worthwhile improvement over the 221-2075001 that was fitted and a tremendous improvement over the 221-2077391 tuner that is often found in the Pace PRD800 receiver.

Note that the export model PSR800 can also be used for this project. It has no internal decoder circuitry, although the modifications are the same.

Satcure can be contacted via their www site:

http://www.netcentral.co.uk/satcure/atv

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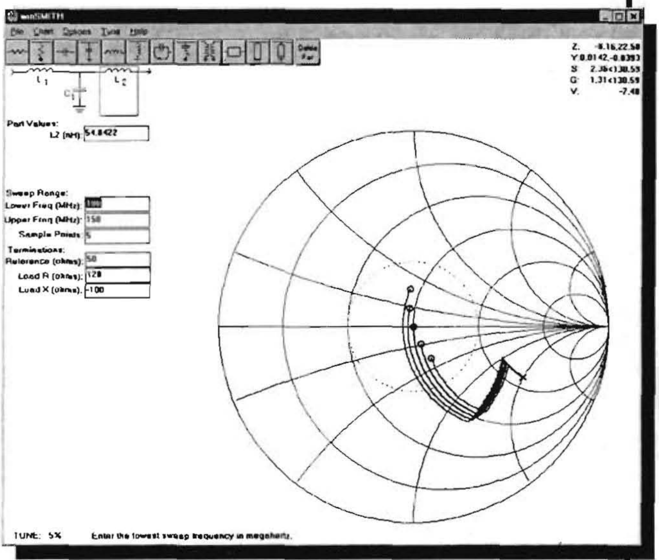

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