Microwave Subsystem

*Part one, by Adrian Knott, G6KSN**

WITH THE introduction of the latest satellite receivers with 2GHz coverage for reception of Astra 1D and now digital, many older receivers have become available on the surplus market. Most of these are keenly priced, typically between £10 and £20. These receivers can be put to good use as the basis of a composite microwave subsystem carrying 625 line colour TV, data at 19200 baud or more (for use as a full duplex packet radio link) and several hi-fi audio channels simultaneously.

The logical (and probably the easiest) frequency band to use is 3cm, which covers 10-10.15GHz and 10.3-10.5GHz. The reason for this choice is fairly obvious; surplus LNBs covering 10.95 to 11.75GHz are readily available, as are Gunn oscillator modules operating between 10.5 and 10.7GHz. These units can be converted to operate in the 10.3-10.5GHz range with relative ease, and suitable dishes with the correct F/D ratio are available for only a few Pounds. Having said this, there is no reason why the system would not operate in any of the bands above 1.2GHz, so long as a Gunn (or DRO etc) oscillator and suitable LNB are available for the band in question.

Workable signals in the 3cm amateur band are generally classed as 'line of sight', especially when low power and wide bandwidths are employed. Most satellite receivers have an IF passband of around 27MHz, allowing for a good video signal-to-noise ratio, even when the carrier-to-noise ratio is only 10dB or so.

A typical Gunn diode oscillator can produce around 10mW of RF. Not much you might think, but when coupled with a high gain dish at each end of the link and a high sensitivity LNB things are not quite as bad as they may at first seem. A 60cm dish at 10GHz will have around 30dB of gain, enough to boost a meagre 10mW up to 10W erp! The use of wideband FM also means that the received carrier-to-noise ratio need only be of the order of 10dB for an acceptable link. Line of sight paths of 50 to 100km now suddenly start to look feasible with this type of equipment.

SUBSYSTEM BOARD

A QUICK LOOK at **Fig 1**, the 'baseband' spectrum of a typical composite signal would be in order before a full explanation of the subsystem (block diagram in **Fig 2**) is given. A typical luminance video signal will occupy up to around 5MHz, any less than this and the picture will gradually lose horizontal resolution. The high frequency end of the spectrum is shared by the colour information at around 4.43MHz. This is possible because of the nature of these two signals. The satellite receiver is capable of handling baseband signals up to around 10MHz, (27 - (3.5 x 2) /2) MHz, where 27MHz is the IF passband and 3.5MHz is the peak video deviation. In practice signals above 8.5MHz are seldom used. The point is that the baseband signal can accommodate several subcarriers that occupy the frequency spectrum above the main video signal.

It is customary to use 6.5MHz (around 75kHz deviation) as the main audio subcarrier and this has been implemented in the prototype, although other frequencies may be used as some satellite receivers will not demodulate a 6.5MHz signal without modification.

Secondary narrowband (50kHz maximum) subcarriers at 7.02 and 7.20MHz have also been included to allow some flexibility on the link and have several potential uses such as stereo shack audio, AFSK data, station identification, etc.

An FSK data signal is included at 6MHz and will operate at all baud rates up to 28800 and beyond. The protocol is RS232 (IBM serial compatible), but must use software handshaking since in effect only TXD and RXD lines are present. The G8BPQ 408 packet switch software will work well here, and an explanation of how to configure BPQ will be included in part two of the article. Other software such as 'Hyperterminal' and similar comms programs can also be made to work and will give slightly higher transfer rates for a given baud rate because of the different protocols used. Both the video and audio signals are subjected to pre-emphasis prior to transmission, in order to improve the overall signal-to-noise ratio.

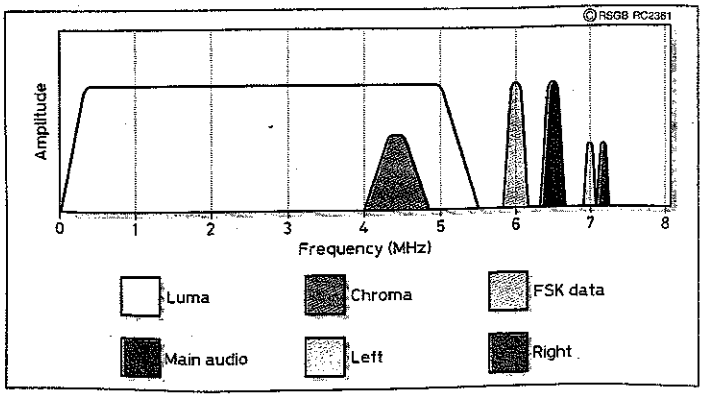

Fig 1: Baseband frequency spectrum of a composite signal.

LNBs

TO RECEIVE the 3cm amateur band it is necessary to move the local oscillator frequency of the LNB from 10.0 (or 9.75GHz) to a lower value. Another possibility would be to lower the lowest frequency receivable on the satellite receiver. In fact there are several possibilities. One is to purchase an LNB ready converted for the job. These generally have the oscillator running at 9.0GHz and thus have full coverage. Another possibility is to use one of the new generation of LNBs with a 9.75GHz local oscillator in addition to an ADX or similar converter which will allow coverage of the top end of the 3cm band.

My experiments with old Marconi 'Blue Cap' LNBs revealed a way of lowering the local oscillator frequency from 10GHz to around 9.3GHz without resorting to anything other than some Evo Stik® and a second 'puck'.

The local oscillator in an LNB has its frequency controlled fairly precisely by a small device akin to a crystal, known as a 'dielectric resonator' or 'puck'. There is no direct electrical connection to the puck, as its proximity to the oscillator circuitry is sufficient to accurately control the frequency. I found that adding a second puck and changing the dielectric constant of the oscillator chamber with glue is sufficient to cause quite a dramatic frequency shift. This may not be the most elegant solution to the problem, but it certainly works!

The front end of the LNB will not quite be tuned to the correct frequency, so sensitivity will be a little down on normal, but unless you have access to a microwave signal generator and spectrum analyser it will have to be tolerated. This method does of course mean that a second puck from a broken LNB is required.

BLUE CAP LNB CONVERSION

ACCESS TO A microwave source (Astra) to determine the effect of the process is important. A suitably located dish set up for Astra in the shack will be found to be very useful. If your shack does not have a south facing window, then you are in trouble.

Firstly, check the LNB's local oscillator frequency by tuning to ZDF. This is the lowest frequency transponder on Astra 1C and is normally the last station that can be tuned-in on an old satellite system (one which utilises an LNB with the local oscillator running at 10.0GHz) when searching from high to low. The satellite receiver should show 963MHz on its display. Make a note of picture quality at this point. It is obviously important that we do not

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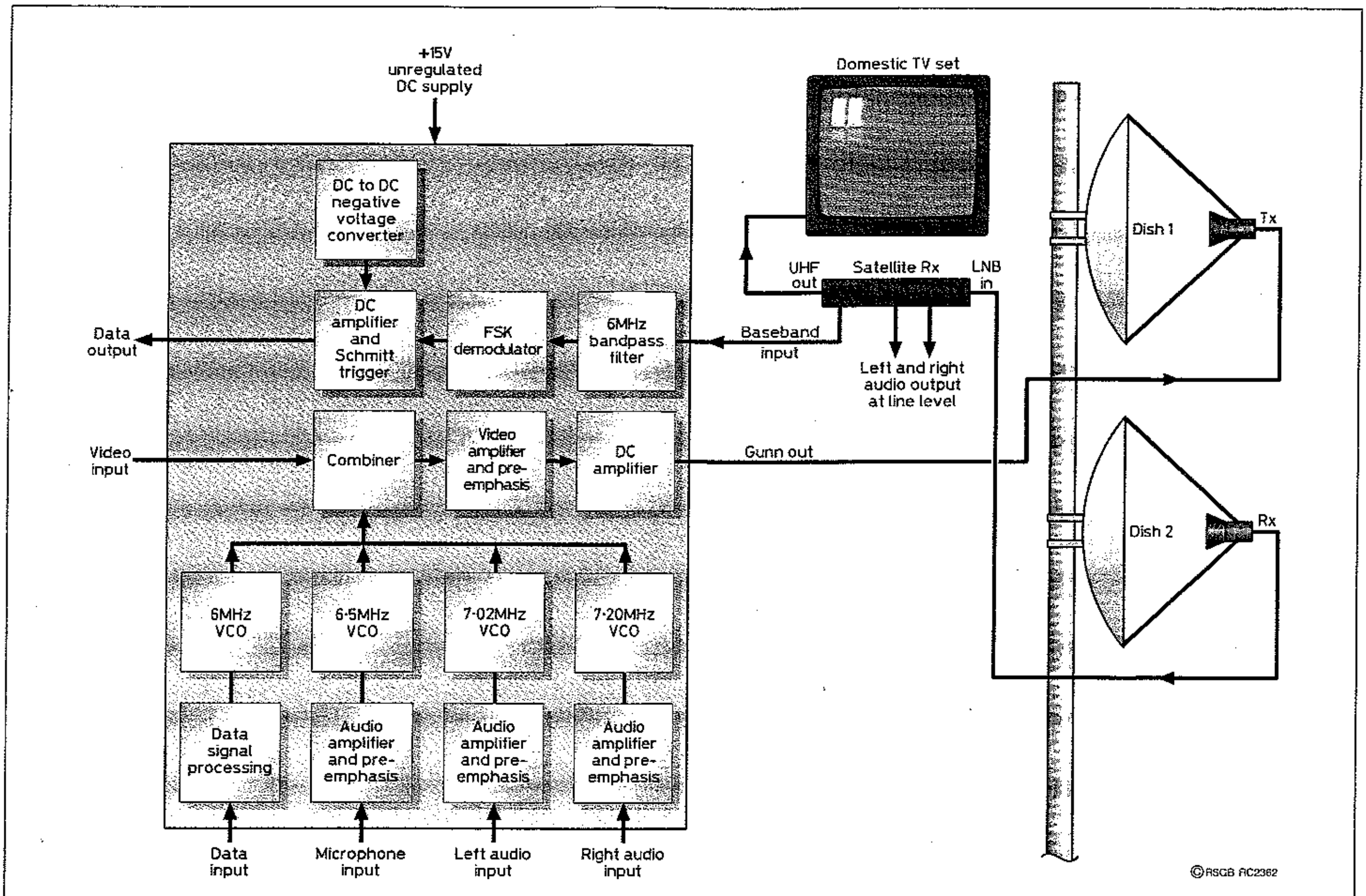

Fig 2: Block diagram of the subsystem.

degrade this too much by our efforts to pull the local oscillator low in frequency. If ZDF is P5 then it should still be so after the modification has taken place.

Drill out the four rivets that hold the back cover of the blue cap LNB in position and remove it. Carefully remove all the Allen screws that hold the aluminium casting in position and store them in a safe place. Glue the second puck in position as shown in **Fig 3** and replace the aluminium casting, but only use two Allen screws to hold it in position temporarily. These Allen screws are very fragile, so only use the minimum force to tighten them. Reassemble the LNB on the dish and check ZDF's new frequency. This should be around 200MHz higher, ie 1163MHz. Tuning the satellite receiver to a lower frequency should reveal Astra 1D at this stage. Undo the adjustment screw on the casting over the oscillator compartment and note that the local oscillator frequency decreases further. Disassemble the LNB again and add a layer of glue within the oscillator compartment, covering both of the pucks and the tuned lines. Allow it to dry for a few minutes and recheck the frequency as before. As the glue dries, the local oscillator frequency will increase slightly. Add several layers of glue over a period of a few hours until the desired effect is achieved, checking the change in frequency each time by monitoring Astra. The frequency stability will be poor until the glue has had a chance harden properly (a day or two). To cover a sufficient part of the 3cm band for full duplex operation, the local oscillator of at least one of the LNBs used on the link must be moved by not less than 600MHz to 9.4GHz.

MAIN BOARD CIRCUIT

REFERRING TO **Fig 4**, IC5 is fed with 15V unregulated, and produces a regulated 12V output to supply the entire circuit. C47, 48 and 49 decouple IC5 and help prevent instability. 1V peak to peak video is fed to R49 and RV8, which together form the required 75Ω termination. A fraction of this video signal is taken from the slider of RV8 and fed through DC blocking capacitor C43 to the base of TR5, which inverts the video signal and also combines the various subcarrier signals which are fed to its emitter through C44. The composite signal thus produced appears on the collector of TR5. TR6 amplifies and once again inverts it. The high frequency gain of this stage is lifted by C46 in the emitter circuit, to pre-emphasise the video. The gain of this stage is substantially flat above 5MHz and so the subcarriers, although amplified, are not pre-emphasised.

The collector of TR6 is DC coupled to the base of TR7, which in conjunction with TR8 forms a Darlington pair. R58 overcomes the internal capacitance of the transistors and helps maintain the HF response. DC negative feedback from the emitter of TR8 is fed back through R60, R86 and RV9 to the base of TR6. The resting DC level at the emitter of TR8 can thus be set by adjusting RV9. R61 in conjunc-

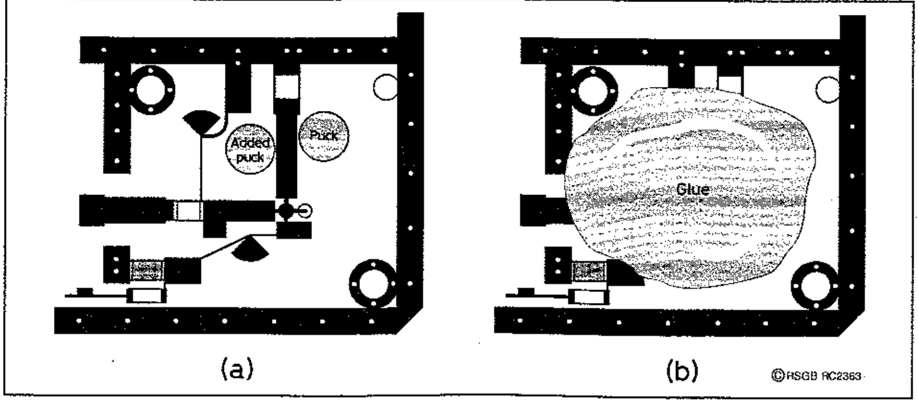

Fig 3: A 'Blue Cap' LNB can be 'pulled' LF using a second puck and Evo Stik®.

tion with the output impedance of TR8 provide a reasonable match to coaxial cable. R61 also acts as a current limiter in the event of a fault ever arising.

The audio subcarrier generators are virtually identical, so only the left 'line' input circuit will be described. Audio at line level feeds to an inverting op-amp, IC1a, through C1, which provides low frequency roll off and DC blocking. The gain of the stage is set by RV1. The op-amp is run from a single-ended supply, so a potential divider consisting of R2 and R6 holds the non-inverting input at half the supply rail and thus provides bias. C2 decouples this supply. The output from IC1a is fed through an equalising network R3, C3, C63, R4 to IC1b, another inverting amplifier. C4 rolls-off the HF response. The amplified, equalised output is fed through a potential divider to lower the DC resting voltage to 3V and then feeds a varicap diode, VD1, through R79. This causes the oscillator based around TR1, L1, C7, C8, C9, C11 etc to become frequency modulated. The centre frequency of oscillation is 7.02MHz for this channel. A fraction of this RF signal is tapped off through R41, RV4 and combined with the other subcarriers through R42.

The data signal which nominally uses ±12V for the two logic levels (note that this input is not TTL compatible) is fed to an inverting comparator which will produce an output of approx +11V for any input less than 5V and approx +1V for any input greater than 7V. This signal is fed to an inverting amplifier whose gain is less than unity and can be adjusted by RV10 to set the deviation to the correct value. C35 and R36 determine the cut-off frequency of the amplifier and form a low pass filter (6dB per octave) to prevent the bandwidth of the resulting FM signal from becoming excessive. The VCO stage is identical to that of the audio subcarrier oscillator stage described previously. The combined subcarrier output is fed via C72 to a common emitter buffer amplifier based around TR10. The output of TR10 feeds the emitter of TR5 via C44.

Referring to **Fig 5**, the unequalised composite baseband signal from the satellite receiver is fed to the primary of L6 via R62. The secondary of L6 is bought to resonance at 6MHz by C67. The secondary tap feeds CF1, a 6MHz ceramic filter. TR9 and associated components form a common emitter amplifier, the output of which feeds a second ceramc filter, CF2. The resultant filtered FSK data signal is fed to a discriminator, IC6, a TBA120S. L5 is the quadrature coil and demodulated data appears at pin 8. This is amplified by IC7a and the zero crossing point is set by RV11. IC7b forms a Schmitt trigger and an RS232 compatible data signal appears at both the outputs of IC7b and IC7c. R75 acts as a current limiter in the event of a fault, and will also help prevent instability if the IC is required to feed a length of screened cable.

IC8 is a 555 timer, configured as an astable

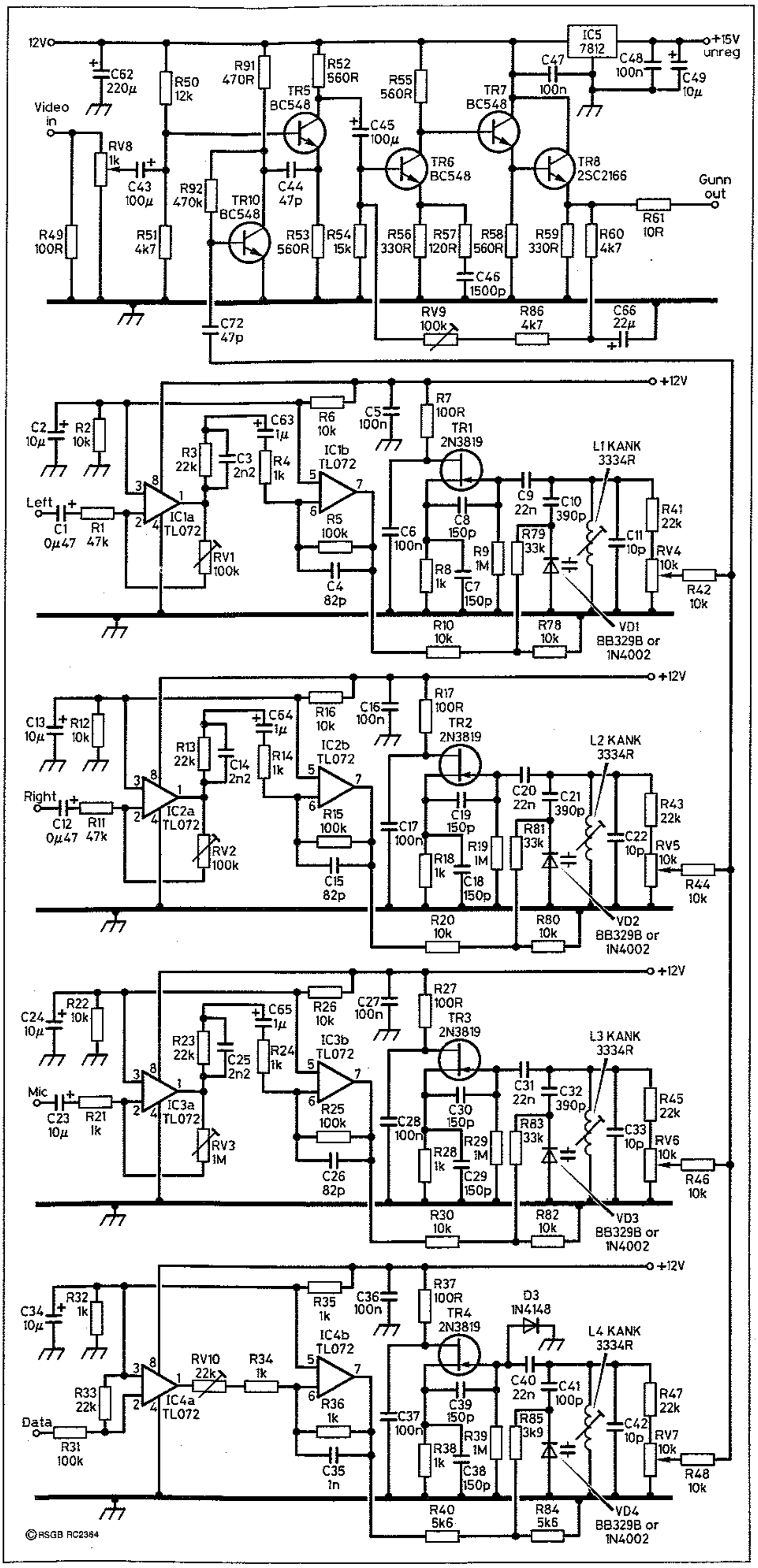

Fig 4: Part of the circuit diagram of the subsystem. Refer to the text for a detailed description.

COMPONENTS

Resistors

R1, 11, 70	47k
R2, 12, 22	10k
R3, 13, 23	22k
R4, 14, 24	1k
R5, 15, 25	100k
R6, 16, 26	10k
R7, 17, 27	100R
R8, 18, 28, 38	1k
R9, 19, 29, 39	1M
R10, 20, 30	10k
R21, 32, 34, 35, 36	1k
R31	100k
R33, 41, 43, 45, 47	22k
R37, 49	100R
R40, 84	5.6k
R42, 44, 46, 48	10k
R50	12k
R51	4.7k
R52, 53	560R
R54	15k
R55, 58	560R
R56, 59, 63, 64	330R
R57	120R
R60, 66, 71, 72	4.7k
R61, 93	10R
R62	82R
R65	270R
R67, 68, 77	22k
R69	56k
R73	1M
R74	1.5k
R75, 91	470R
R76, 86	4.7k
R78, 80, 82	10k
R79, 81, 83	33k
R85	3.9k
R87, 92	470k
R88	330R
R89	1k
R90	100R
RV1, 2, 9, 11	100k
RV3	1M
RV4, 5, 6, 7	10k
RV8	1k
RV10	22k

Capacitors

C1	0.47μF 10V electrolytic
C2	10μF 10V electrolytic
C3, 14, 25	2.2nF polyester
C4, 15, 26	82pF ceramic plate
C5, C6	100nF polyester
C7, C8	150pF ceramic plate
C9, 31	22nF polyester
C10, 32	390pF ceramic plate
C11, 33	10pF ceramic plate
C12	0.47μF 10V electrolytic
C13, 34	10μF 10V electrolytic
C16, 17	100nF polyester
C18, 19	150pF ceramic plate
C20	22nF polyester
C21	390pF ceramic plate
C22	10pF Cceramic plate
C23, 24	10μF 10V electrolytic
C27, 28	100nF polyester
C29, 30	150pF ceramic plate
C35	1nF ceramic disc
C36, 37	100nF polyester
C38, 39	150pF ceramic plate
C40	22nF polyester
C41	100pF ceramic plate
C42	10pF ceramic plate
C43, 45	100μF 16V electrolytic
C44	47pF ceramic plate
C46	1500pF ceramic plate
C47, 48	100nF polyester
C49, 50	10μF 25V electrolytic
C51, 52	22nF ceramic plate
C53	1nF ceramic plate
C54	220pF ceramic plate
C55	100nF polyester
C56	22nF polyester
C57	100μF 25V electrolytic
C58, 61	100nF polyester
C59, 60	220μF 16V electrolytic
C62	220μF 16V electrolytic
C63-65	1μF 16V electrolytic
C66	22μF 16V electrolytic
C67	270pF ceramic plate
C68	10nF polyester
C69	2.2nF polyester
C70, 71	22nF polyester
C72	47pF ceramic plate

Semiconductors

TR1, 2, 3, 4	2N3819
TR5, 6, 7	BC548
TR8	2SC2166
TR9, 10	BC548
IC1, 2, 3, 4	TL072
IC5	7812
IC6	TBA120S
IC7	TL084
IC8	NE555
D1, 2, 3	1N4148
VD1, 2, 3, 4	BB329B or 1N4002
LED1	Red 0.2in
LED2	Green 0.2in

Miscellaneous

L1-L6	Toko KANK3334R
CF1, 2	SFE 6.0MB 6MHz ceramic
PCB	Veropins Case

Sockets for video, audio, data, power input and Gunn supply
Knobs for some functions (but can be preset)

multivibrator. It provides the negative supply for IC7. A high frequency square wave appears at pin 3 and is fed through C57 to a diode pump circuit, D1 and D2, the output of which is filtered by C58 and C59. This produces around -9V, a fraction less than the positive supply rail (but this is of no consequence). ◆

To be continued...

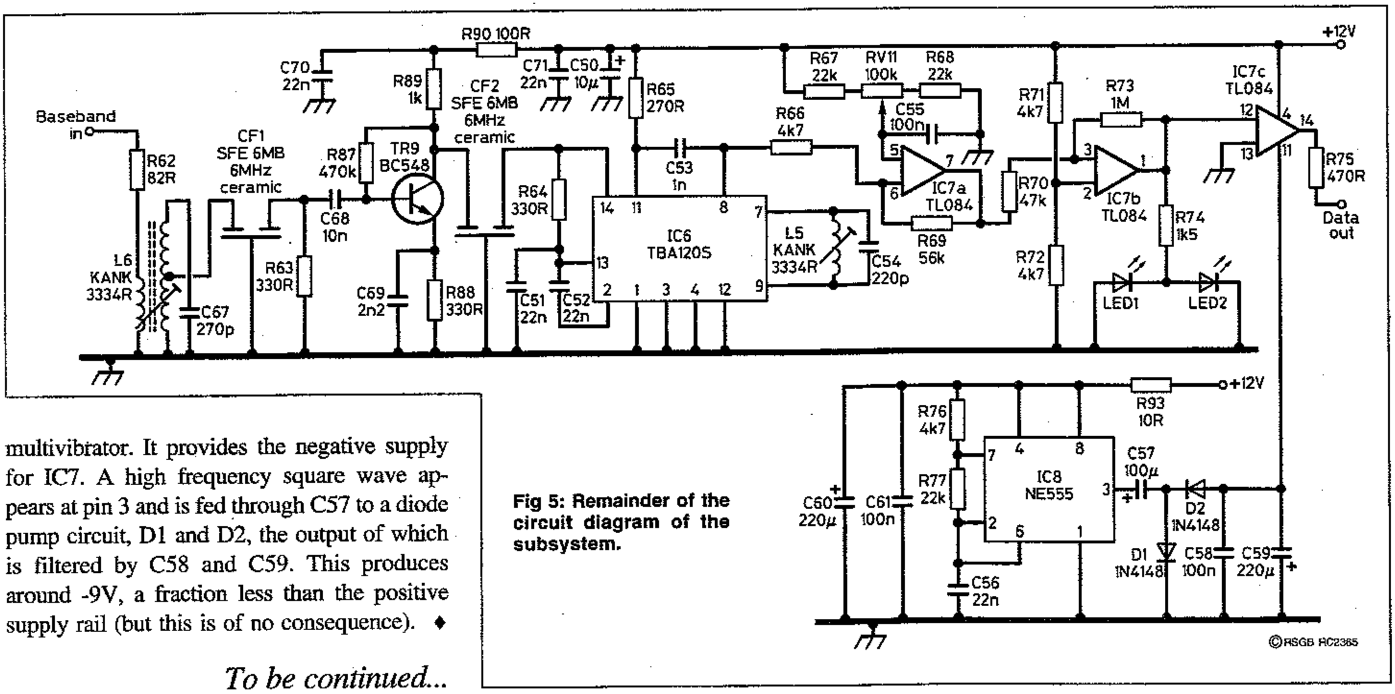

Fig 5: Remainder of the circuit diagram of the subsystem.