RF signal generator

part 1: circuit descriptions

An RF signal generator is used for repairing radio/TV circuits, checking filters, aligning receivers, and for comparative sensitivity tests on all kinds of receivers, whether home-made, restored surplus or off-the-shelf. The generator described here has an output frequency range of 0.5 to 30 MHz, making it suitable for many applications.

Main specifications

- Frequency range: 0.5 MHz to 30 MHz
- Output level: 0 dBm down to –79 dBm in 1-dB steps
- Max. output level: 0.63V_{pp} into 50 Ω
- Output impedance: 50 Ω
- AM input
- FM input
- LCD readout
- Microprocessor controlled
- Optional serial interface

Design by Guido Brunner

A rock-solid RF signal with an accurately known frequency and level is a must for anyone seriously involved in repairing radio receivers and other communications equipment like filters and even antennas. In particular, receiver RF input and IF (intermediate frequency) sections can not be tested with any degree of certainty if a trustworthy RF signal generator is not to hand. Unfortunately, professional-grade RF signal generators (like the mighty Hewlett Packard 8640B in our design lab) cost an arm and a leg, even in the surplus trade. None the less, you will see at least one RF signal generator, home-made, thrown together from other bits and pieces, or ex-MOD, in the shack of the more advanced radio amateur, simply because this piece of test gear is as indispensable as the plain old multimeter.

The stability of the RF signal generator described in this article is such that it will meet the (moderate) demands of many amateurs. Offering a frequency range of 0.5 through 30 MHz and an output level down to –80 dBm, it is perfect for testing and aligning many receivers and their sub-circuits like RF/IF amplifiers, mixers and demodulators.

What requirements can be mentioned in relation to an RF signal generator? The answer is very simple indeed: you need to be sure of (1) the *frequency* and (2) the *level* of the signal you feed into the circuit (receiver) under test. If either of these is unreliable, all testing and comparing of receiver specs becomes meaningless. In the present design, frequency stability is assured by a PLL (phase-locked loop), while the output level is determined by a switched pi (pi) attenuator, all under the control of a microprocessor.

BLOCK DIAGRAM

Because the actual circuit diagrams of the four modules that make up the signal generator are a fairly complex lot when presented together, it was decided to draw and discuss them as separate blocks. The basic interaction of these blocks is illustrated in **Figure 1**. The block diagram shows that the heart of the circuit is a PLL synthesizer module keeping a VCO (voltage-controlled oscillator) in check. The VCO output signal is amplified and fed to the generator output as well to the synthesizer input and the input of the attenuator. The PLL obtains digital information on the target VCO frequency from a microprocessor module. The micro also takes care of the front-panel mounted user interface, which consists of 3 switches, a rotary encoder and an LCD (liquid-crystal display). It also controls the amount of attenuation at the generator output, across a range of –1 dB through –79 dB. An optional serial interface is available to enable the RF Signal Generator to be linked to a PC using an RS232 cable. Functionally, the instrument is completed by an internal power supply.

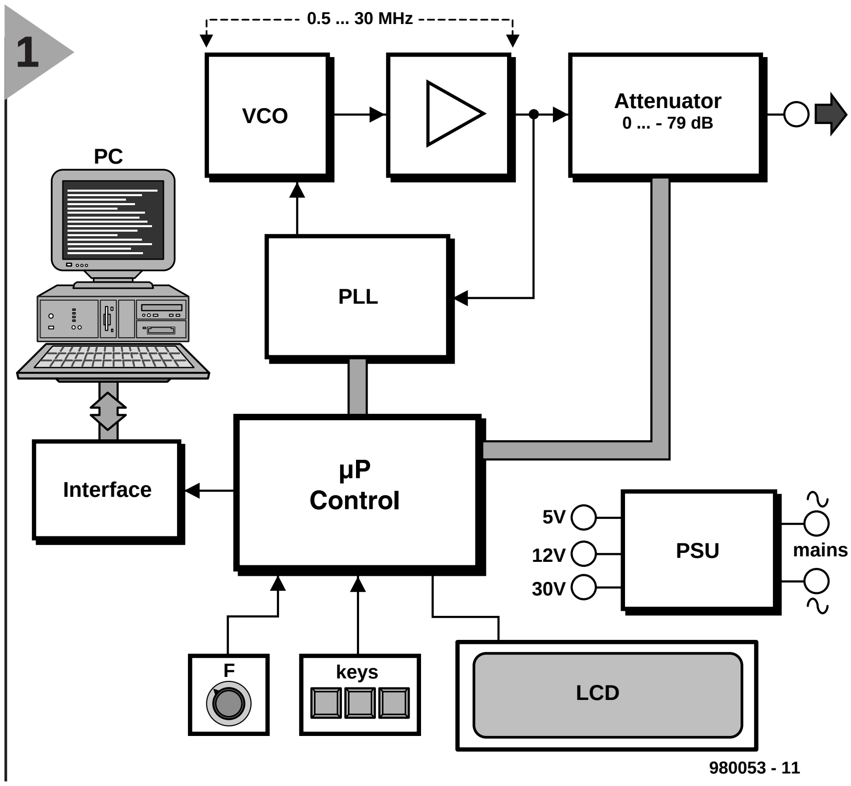

Figure 1. Block diagram of the RF Signal Generator. All intelligence is vested in a microcontroller.

PLL BOARD

The circuit diagram of this first module to be discussed in detail is shown in **Figure 2**. It comprises three sub-circuits: VCO, synthesizer and output buffer. The VCO and the synthesizer together from the PLL.

VCO and buffers

The active element in the oscillator is a differential amplifier built around transistors T1, T2 and T3, whose gain depends on the current passed by T3. The actual resonating element in the oscillator is an L-C parallel tuned circuit connected to the input of the difference amplifier. The LC network consists of inductors L1-L5 in combination with variable-capacitance diodes (varicaps) D9 and D10. The other input of the oscillator is grounded for RF by capacitor C10. Depending on the desired frequency range, one or more inductors are switched into the oscillator. This is done by pulling the non-commoned terminals to RF ground using +5V control voltages on PIN diodes D2, D4, D6 and D8. In the highest frequency range, all inductors are effectively connected in parallel. This is necessary to make sure that the non-selected inductors and their parasitic capacitance can not form a series tuned circuit that would prevent the oscillator from operating at the desired frequency. All inductors are off-the-shelf miniature chokes. The frequency range switching takes place at 1.024 MHz, 2.304 MHz, 5.376 MHz and 13.056 MHz.

Capacitor C8 provides the necessary amount of positive feedback in the oscillator. An AF signal may be applied to the emitter of T4 to effect amplitude modulation (AM). Frequency modulation (FM) is also possible by superimposing an AF signal onto the varicap tuning voltage. Although FM will cause the PLL to drop out of lock, the average frequency remains constant because the time constant of the control loop is not capable of tracking the 'instability' caused by the modulation signal.

To make sure it is not too heavily loaded, the oscillator signal is first buffered by a FET (field-effect transistor), T4. Next comes the real amplifier, IC1, a type NE592 which some of you may know from baseband-video amplifiers in satellite-TV receivers. The amplifier is biased at half the supply voltage by opamp IC3b, and its gain is defined by series network R26-L8. Because of the inductor action, the gain decreases at higher frequencies. Because the VCO strives to maintain a stable output level, less gain on the NE592 automatically more gain in the differential oscillator. This purposely-created effect is essential for reliable starting of the oscillator at higher frequencies.

The NE592 being a differential amplifier, it has two inputs, but also outputs. Both are used here. The signal at the first output (pin 7) is applied to emitter follower T5 which supplies the actual generator output signal at an impedance of 50 Ω (the standard in RF test equipment). The other output signal supplied by the NE592 is used to drive two sub-circuits. One branch goes to the PLL chip via C23 and R33, the other is used to drive a voltage rectifier/doubler, D11-D12 which in turn drives amplitude-control opamp IC3a. The desired highest output amplitude may be set using preset P1. The author used a setting where 0 dBm (decibel-

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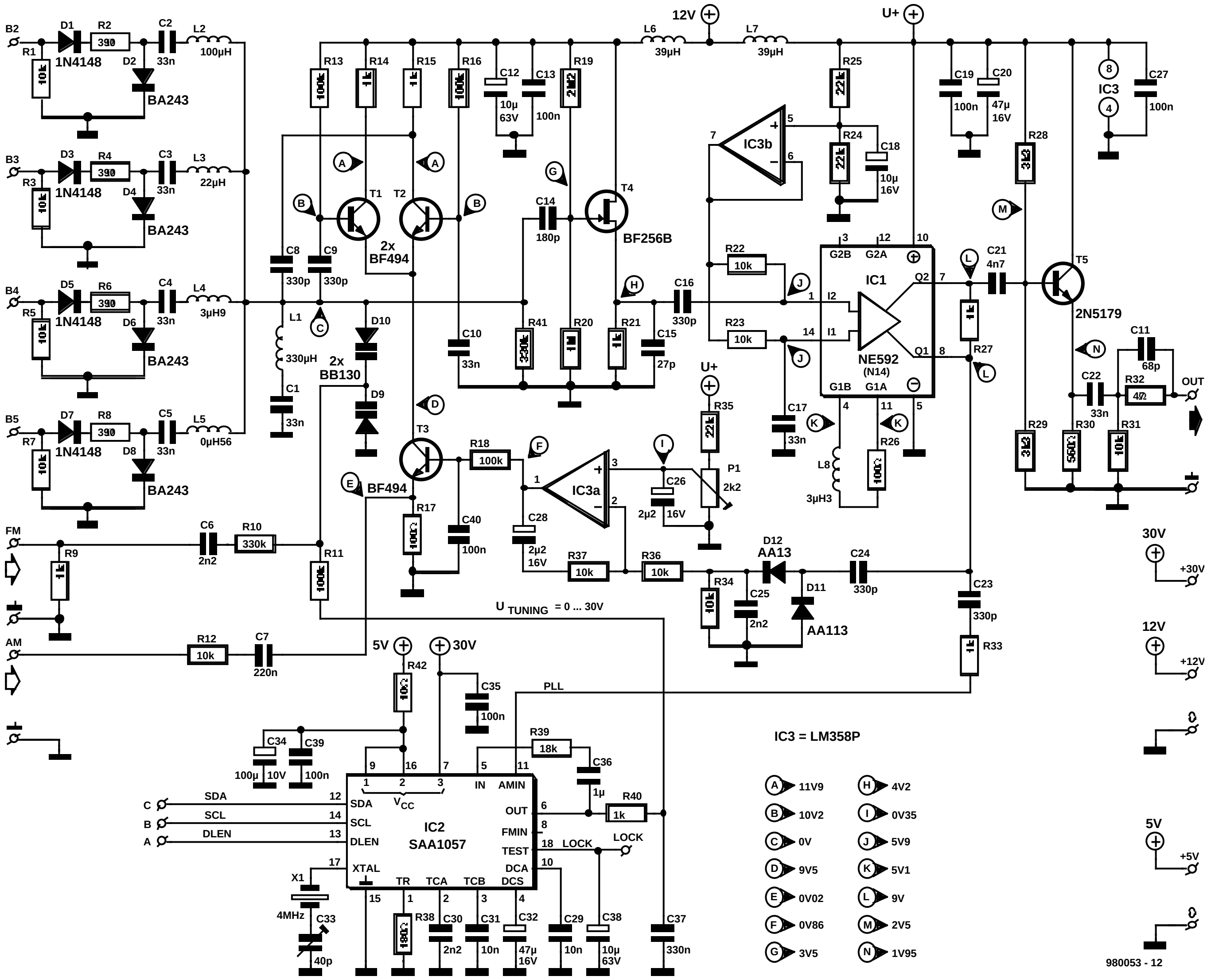

B2
B3
B4
B5
D1
D3
D5
D7
1N4148
D2
D4
D6
D8
BA243
R1
R3
R5
R7
10k
R2
R4
R6
R8
390
C2
C3
C4
C5
33n
L2
100µH
L3
22µH
L4
3µH9
L5
0µH56
L1
330µH
C1
33n
FM
C6
2n2
R10
330k
R9
1k
R11
100k
AM
R12
10k
C7
220n
R13
100k
R14
1k
R15
1k
R16
100k
C8
330p
C9
330p
T1
T2
2x
BF494
D10
2x
BB130
D9
T3
BF494
R17
100Ω
C40
100n
R18
100k
C12
10µ
63V
C13
100n
R19
2M2
C14
180p
T4
BF256B
C10
33n
R41
330k
R20
1M
R21
1k
C15
27p
12V
L6
39µH
L7
39µH
U+
R25
22k
R24
22k
C18
10µ
16V
IC3b
C16
330p
R22
10k
R23
10k
IC1
NE592
(N14)
G2B
G2A
G1B
G1A
I2
I1
Q2
Q1
C17
33n
L8
3µH3
R26
100Ω
R35
22k
P1
2k2
C26
2µ2
16V
IC3a
C28
2µ2
16V
R37
10k
R36
10k
R34
10k
C25
2n2
D12
AA13
D11
AA113
C24
330p
C23
330p
R33
1k
R27
1k
C21
4n7
T5
2N5179
C19
100n
C20
47µ
16V
IC3
C27
100n
R28
3k3
R29
3k3
R30
560Ω
R31
10k
C22
33n
R32
47Ω
C11
68p
OUT
U TUNING = 0 ... 30V
5V
30V
R42
10Ω
C35
100n
PLL
C34
100µ
10V
C39
100n
R39
18k
C36
1µ
R40
1k
IC2
SAA1057
SDA
SCL
DLEN
XTAL
VCC
IN
AMIN
OUT
FMIN
TEST
DCA
DCS
TR
TCA
TCB
LOCK
C
B
A
X1
4MHz
C33
40p
R38
180Ω
C30
2n2
C31
10n
C32
47µ
16V
C29
10n
C38
10µ
63V
C37
330n
IC3 = LM358P
A 11V9
B 10V2
C 0V
D 9V5
E 0V02
F 0V86
G 3V5
H 4V2
I 0V35
J 5V9
K 5V1
L 9V
M 2V5
N 1V95
30V
+30V
12V
+12V
5V
+5V
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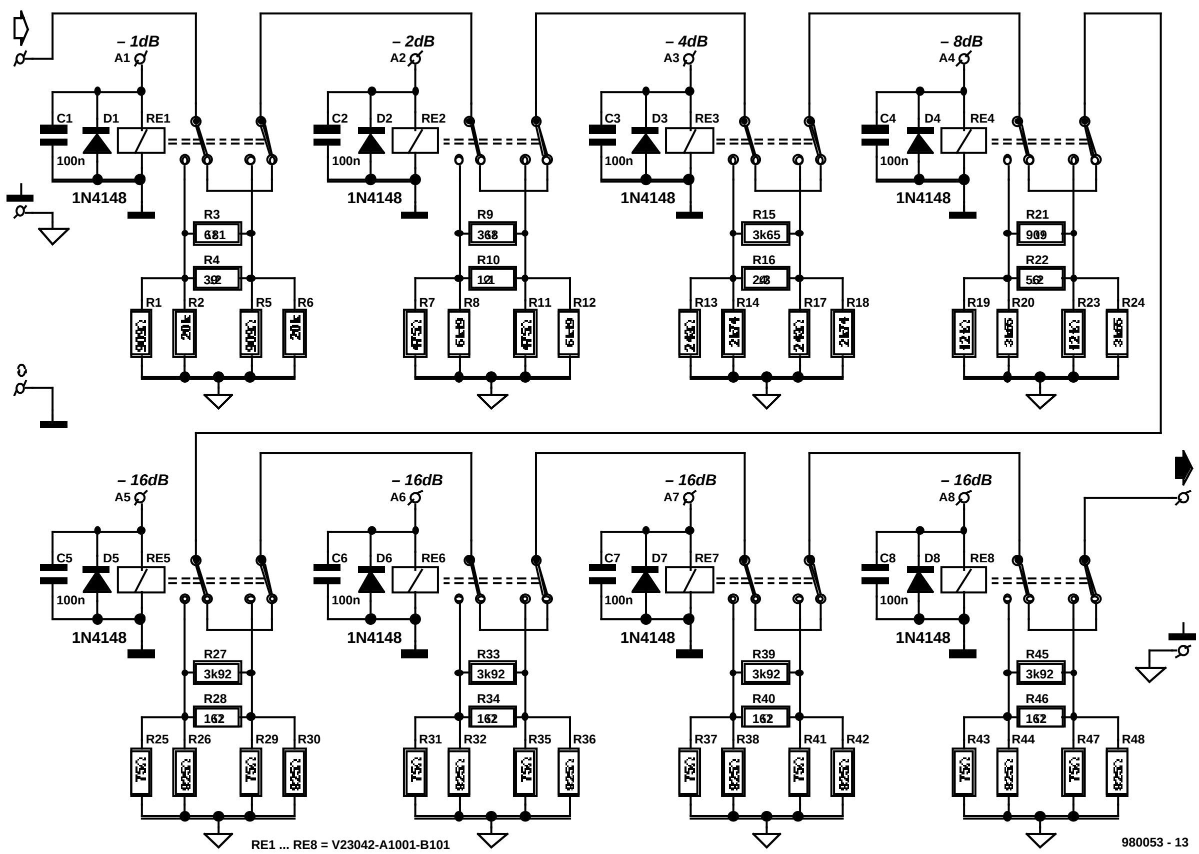


– 1dB
A1
– 2dB
A2
– 4dB
A3
– 8dB
A4
– 16dB
A5
A6
A7
A8
C1
C2
C3
C4
C5
C6
C7
C8
100n
D1
D2
D3
D4
D5
D6
D7
D8
1N4148
RE1
RE2
RE3
RE4
RE5
RE6
RE7
RE8
R3
681
R4
392
R1
909Ω
R2
20k
R5
909Ω
R6
20k
R9
365
R10
121
R7
475Ω
R8
6k19
R11
475Ω
R12
6k19
R15
3k65
R16
243
R13
243Ω
R14
2k74
R17
243Ω
R18
2k74
R21
909
R22
562
R19
121Ω
R20
3k65
R23
121Ω
R24
3k65
R27
R33
R39
R45
3k92
R28
R34
R40
R46
162
75Ω
825Ω
RE1 ... RE8 = V23042-A1001-B101
980053 - 13

igure 2. Circuit diagram of e VCO/PLL board. The heart f the PLL is an I²C-controlled ynthesizer chip type AA1057.

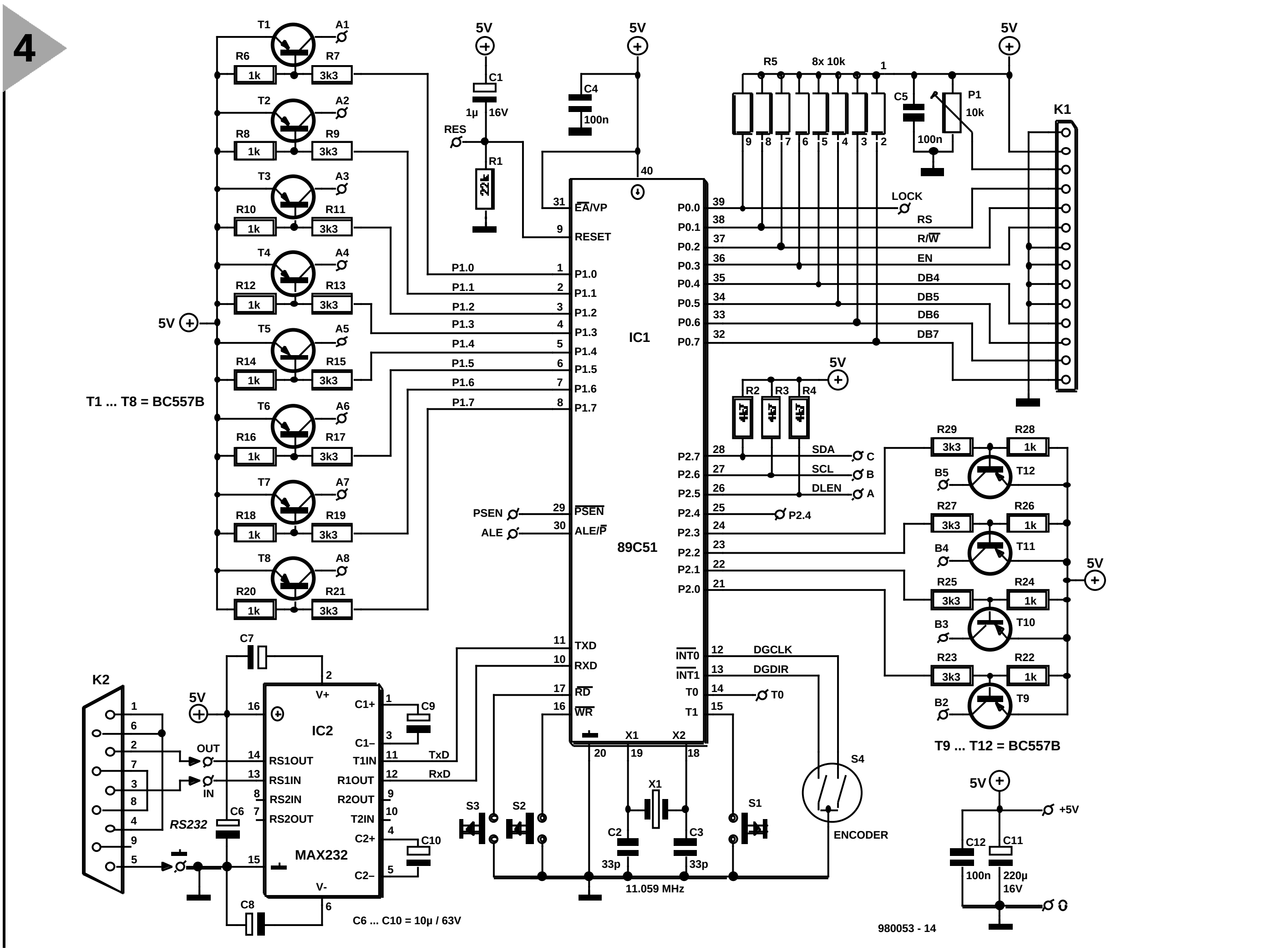
milliwatt) into 50 Ω equals 0.63 V_{pp} at the generator output.

Synthesizer

The circuit of the synthesizer largely follows the Application Note for the SAA1057 as supplied by Philips Semiconductors. Some component values in the control loop had to be modified a little to optimise the behaviour of the PLL. The 'LOCK' output is only provided for test purposes. The SAA1057 receives its control information in I2C format via its SDA, SCL and DLEN inputs. These lines are connected to a microcontroller. Basically, the SAA1057 compares the frequency of the VCO with that of a reference signal derived from the external 4-MHz quartz crystal. For this purpose the VCO signal is internally divided by a factor determined by the microprocessor. The frequency difference produces an error signal which is converted into a corresponding varicap control voltage. This control voltage is integrated by R40-C37 and has a range of 0-30 V. Remarkably, the SAA1057 does not require an external level converter for the varicap control voltage — a special amplifier is included on the chip for this purpose, as well as a direct connection for +30 V (pin7).

Trimmer C33 allows the generator output frequency to be calibrated against a frequency standard.

The VCO/PLL board requires three supply voltages: +5 V for the synthesizer, +12 V for the VCO, and +30 V for the varicap voltage.



igure 3. Circuit diagram of e digitally controlled attenuator. Range is –1 dB to –79 dB 1-dB steps.

Figure 4. Circuit diagram of the controller board. An 89C51 sits between a number of input and output devices.

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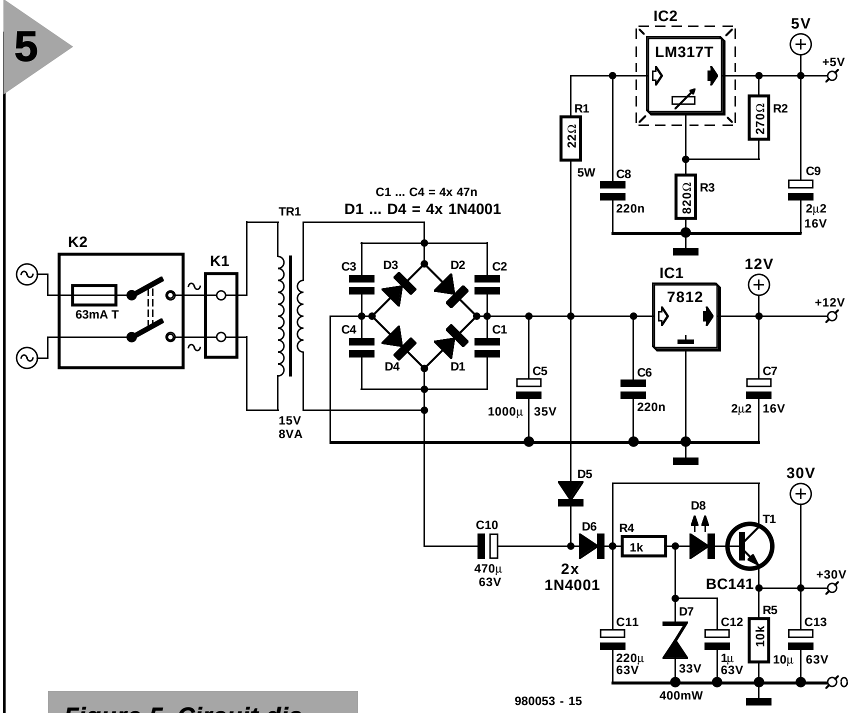

Figure 5. Circuit diagram of the power supply. Three voltages from one transformer!

ATTENUATOR BOARD

Figure 3 shows the circuit diagram of a digitally controlled 8-section pi RF attenuator with a range of –1 dB to –79 dB in 1-dB steps. The resistor combinations we need to realize each of the 79 discrete attenuation levels are connected into the circuit by means of relay contacts. The associated relays are actuated and de-actuated by microprocessor drive signals that form 8-bit combinations at the control inputs marked A1-A8.

The theoretical values of the resistors in the attenuator are realized by means of parallel combinations of 1% resistors from the E96 series.

Each relay coil is shunted by a back-emf suppressor diode and a decoupling capacitor.

MICROCONTROLLER BOARD

All the intelligence we need to implement a man/machine interface, i.e., establish communication between the user on the one hand, and the PLL and the attenuator on the other, is packed in a microcontroller type 89C51. This controller executes a program written by the author and burned into the internal program memory by the Publishers. The 89C51 is available ready-programmed from the Publishers or certain kit suppliers advertising in this magazine.

The 89C51 accepts information and supplies information. Microcontroller freaks call this 'I/O' for input/output. Well, the input devices are a rotary shaft encoder, S4, which is used for the frequency setting, a small keyboard, S1-S2-S3, the SDA line of the I^2C bus and (optionally) the RxD line of the MAX232 serial interface. The output devices to control are the LCD connected to port P0, the attenuator on port P1), the VCO inductors on port line P2.0 through P2.3 and, of course, the synthesizer chip, by way of the DDA and SCL lines (P2.6 and P2.7). Actually, the I^2C bus is modified into a so-called CBUS by the addition of P2.5 (DLEN) and its pull-up resistor, R2.

The 89C51 is clocked at 11.0592 MHz by an external quartz crystal, X1. This frequency was chosen because it allows standard baud rates to be used on the serial interface.

A classic power-on reset network, R1-C1, completes the microcontroller circuit.

This board requires only +5 V to operate, the MAX232 having on-chip step-up converters for +10 V and –10 V.

POWER SUPPLY BOARD

As you can see from the circuit diagram in Figure 5, the power supply for the RF signal generator is entirely conventional.

The 30-V varicap supply is based on a simple combination of a zener diode and a series transistor. Current drain on the 30-V rail will be very small, so extensive regulation is not necessary. None the less, a fair number of decoupling capacitors is used to keep the varicap voltage as clean as possible. After all, all hum, noise etc. on this rail will cause frequency modulation on the output signal. The input voltage for the 30-V regulator is supplied by a voltage doubler, C10-D5-D5.

The 5-V and 12-V supplies are based on two old faithfuls, the 7805 and the LM317 respectively. These ICs and their usual 'satellite' components have been used so many times in our published circuits that no further description will be necessary.

A single mains transformer rated at 15 V, 8VA, supplies all the necessary alternating voltages. The mains voltage at the primary side is applied via a double-pole switch and a fuse, both built into a Euro-style appliance socket.

NEXT MONTH

In next month's second and concluding instalment we will be discussing the construction of the instrument on four printed circuit boards. The article will be concluded with notes on the operation of the RF Signal Generator, miscellaneous matters and optional extras.

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