TG1010

Programmable 10 MHz
DDS Function Generator
Service Manual

Book Part Number 48591-0470 - Issue 1.

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Specifications

Specifications apply at 18°-28°C after one hour warm-up, at maximum output into 50Ω

FREQUENCY

Range:	0·1 mHz to 10 MHz.
	All waveforms are available up to 10 MHz. However, the purity of triangle, ramp and multi-level squarewave waveforms is not specified above the frequencies indicated in the appropriate WAVEFORM section. In Arbitrary mode all waveform points are continuously output up to approximately 27 kHz beyond which they are sampled.
Resolution:	0·1mHz (7 digits)
Accuracy:	Typically ± 10 ppm for 1 year, 18°C to 28°C
Temperature Stability:	Typically <1 ppm/°C

SYMMETRY

Range:	Sine, Triangle, Ramp - 1% to 99% at all frequencies Squarewave,Pulse - 1% to 99% to 30kHz, 20% to 80% to 10MHz.
Resolution:	0·1%

WAVEFORMS

Sine, square, positive pulse, negative pulse, multi-level squarewave, triangle, ramp up, ramp down, DC, ARB and Noise.

Sinewave

Output level:	5mV to 20V p-p open circuit o/p.
Harmonic Distortion:	<0·3% THD to 500kHz; <-50dBc to 1MHz, <-35dBc to 10MHz.
Non-harmonic Spurii:	typically <-55dBc to 10MHz.

Squarewave

Output level:	5mV to 20V p-p open circuit o/p.
Rise and Fall Times:	<25ns

Triangle

Output level:	5mV to 20V p-p open circuit o/p.
Linearity error:	<0·5% to 30 kHz

Positive and Negative Ramp

Output level:	5mV to 20V p-p open circuit o/p.
Linearity error:	<0·5% to 30 kHz

Positive and Negative Pulse

Output level:	2·5mV to 10V p-p open circuit o/p.
Rise and Fall Times:	<25ns

Multi-Level Squarewave

Up to 16 steps available per cycle, each step selectable for amplitude (10 bit resolution) and duration (1 to 1024 samples). Allows generation of 3 level squarewave, staircase, multiplexed LCD driver signals etc.

Frequency Range:	All waveform points can be continuously output up to approximately 27kHz, above which sampling will introduce a 1 clock edge uncertainty (1 clock = 36ns).
Output level:	5mV to 20V p-p open circuit o/p.
Rise and Fall Times:	<25ns

Arbitrary

A number of frequently required waveforms are pre-programmed in ROM. Alternatively, waveforms can be downloaded via the generator's RS232 or GPIB interfaces and stored in non-volatile RAM.

Frequency range:	All waveform points can be continuously output up to approximately 27 kHz, above which they are sampled.
Output level:	5mV to 20V p-p open circuit o/p.
Number of samples:	1024
Sample levels:	1024 (10 bits)

HOP

Up to 16 different waveforms can be output in sequence at a rate determined by either the internal timer, an external trigger a remote command, or from the keyboard. Each waveform can be set to any waveshape (except noise), frequency, amplitude and offset. Frequency only changes are phase-continuous.

Noise

White noise output with a typical -3dB bandwidth of 0.03Hz to 700kHz. Amplitude and offset adjustable. Noise can only be used with Gated and AM modulation modes.

MODULATION MODES

Trigger/Burst

Phase coherent signal keying - each positive edge of the trigger signal will produce one burst of the carrier, starting and stopping at the phase angle specified by the Start/Stop phase setting.

Carrier frequency:	0·1mHz to at least 1MHz
Carrier waveforms:	All.
Number of cycles:	1 to 1023 (resolution 1 cycle) or 0·5 to 511·5 (resolution 0·5 cycle).
Trigger rep. rate:	dc to 50 kHz internal, dc to 1MHz external.
Source:	Internal from keyboard or trigger generator. External from EXT TRIG input or remote interface.

Gated

Non-phase coherent signal keying - output carrier wave is on while Gate signal is high and off while low.

Carrier frequency:	From 0·1 mHz to 10 MHz.
Carrier waveforms:	All
Trigger rep. rate:	dc to 50 kHz internal, dc to 1 MHz external.
Gate signal source:	Internal from keyboard or trigger generator. External from EXT TRIG input or remote interface.

Sweep

Carrier Waveforms:	All
Sweep Mode:	Linear or logarithmic, single or continuous.
Sweep Width:	From 0·1 mHz to 10 MHz in one range. Phase continuous. Independent setting of the start and stop frequency.
Sweep Time:	10ms to 999s (3 digit resolution).
Markers:	Two, variable during sweep. Available at the rear panel TRIG/SWEEP OUT socket.
Sweep Trigger source:	The sweep may be free run or triggered from any of the following sources: Internal from keyboard. External from EXT TRIG input or remote interface.

Amplitude Modulation

Carrier frequency:	From 0·1mHz to 10 MHz.

Carrier waveforms:	All.
Depth:	Variable 0 to 100% typical, resolution 1%.
Internal source:	1 kHz fixed sinewave or 0·005 Hz to 50 kHz squarewave.
External:	See VCA In

Frequency Shift Keying (FSK)

Phase coherent switching between two selected frequencies at a rate defined by the switching signal source.

Carrier frequency:	From 0·1mHz to 10 MHz.
Carrier waveforms:	All.
Switch repetition rate:	dc to 50 kHz internal, dc to 1 MHz external.
Switching signal source:	Internal from keyboard or trigger generator. External from EXT TRIG input or remote interface.

Start/Stop Phase

Carrier frequency:	0·1 mHz to at least 1MHz.
Carrier waveforms:	All.
Range:	-360 to +360 degrees.
Resolution:	1 degree.
Accuracy:	Typically 1 degree to 30 kHz.

Trigger Generator

Internal source 0·005 Hz to 50 kHz squarewave adjustable in 20µs steps. 3 digit resolution. Available for external use from TRIG/SWEEP OUT socket.

OUTPUTS

Main Output

Output Impedance:	50Ω or 600Ω
Amplitude:	5mV to 20V pk-pk open circuit, (2·5mV to 10V pk-pk into 50Ω/600Ω). Output can be specified as EMF (open circuit value) or P.D (potential difference) in pk-pk, r.m.s. or dBm.
Amplitude Accuracy:	typically ±3% ±1mV at 1kHz into 50Ω/600Ω.
Amplitude Flatness:	±0·2dB to 200 kHz; ±1dB to 5 MHz; ±2·5dB to 10 MHz.
DC Offset Range:	±10V. DC offset plus signal peak limited to ±10V from 50Ω/600Ω.
DC Offset Accuracy:	typically ±3% ±10mV, unattenuated.
Resolution:	3 digits or 1mV for both Amplitude and DC Offset.
Pulse Aberrations:	<5% + 2mV.

Aux Out

CMOS/TTL levels with symmetry and frequency of main output and phase of Start-Stop Phase setting.

Trig/Sweep Out

Multifunction output depending upon mode. Except in Sweep and HOP modes the output is that of the Trigger Generator at CMOS/TTL levels from 1kΩ. In Sweep mode the output is a 3-level waveform, changing from high (4V) to low (0V) at start of sweep, with narrow 1V pulses at each marker point. In HOP mode the output goes low at the entry to each step, followed by a rising edge after the frequency and waveshape have changed for the new step.

INPUTS

Ext Trig

Frequency Range:	DC - 1 MHz.
Signal Range:	Threshold nominally TTL level; maximum input ±10V.

Minimum Pulse Width:	50ns, for Trigger, Gate and FSK modes; 1ms for Sweep and HOP modes.
Input Impedance:	10kΩ

VCA In

Frequency Range:	DC - 100 kHz.
Signal Range:	2·5V for 100% level change at maximum output.
Input Impedance:	typically 6kΩ.

PHASE LOCKING

The signals from these sockets are used to phase lock two or more generators.

Clock In/Out

TTL/CMOS threshold level as an input. Output logic levels nominally 1V and 4V from typically 50Ω as an output.

Sync Out

TTL/CMOS logic levels from typically 50Ω.

INTERFACES

Full remote control facilities are available through the RS232 (standard) or optional GPIB interfaces.

RS232:	Variable Baud rate, 9600 Baud maximum. 9-pin D-connector. Fully compatible with Thurlby-Thandar ARC (Addressable RS232 Chain) system.
IEEE-488:	Conforming with IEEE488.1 and IEEE488.2

GENERAL

Display:	20 character x 4 row alphanumeric LCD.
Data Entry:	Keyboard selection of mode, waveform etc.; value entry direct by numeric keys or by rotary control.
Stored Settings:	Up to 9 complete instrument set-ups may be stored and recalled from battery-backed memory.
Size:	3U (130mm) height; half-rack (212mm) width; 330mm long.
Weight:	4·1kg. (9lb.)
Power:	230V, 115V or 100V nominal 50/60Hz, adjustable internally; operating range ±14% of nominal; 30VA max.
Operating Range:	+5°C to 40°C, 20-80% RH.
Storage Range:	-20°C to + 60°C.
Options:	IEEE-488 interface; 19 inch rack mounting kit.
Safety:	Complies with EN61010-1.
EMC:	Complies with EN55011 and EN50082-1.

Safety

This function generator is a Safety Class I instrument according to IEC classification and has been designed to meet the requirements of EN61010-1 (Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use). It is an Installation Category II instrument intended for operation from a normal single phase supply.

This instrument has been tested in accordance with EN61010-1 and has been supplied in a safe condition. This service manual contains some information and warnings which have to be followed by the user to ensure safe operation and to retain the instrument in a safe condition.

This instrument has been designed for indoor use in a Pollution Degree 1 environment (no pollution, or only dry non-conductive pollution) in the temperature range 5°C to 40°C, 20% - 80% RH (non-condensing). It may occasionally be subjected to temperatures between +5° and -10°C without degradation of its safety.

Use of this instrument in a manner not specified by these instructions may impair the safety protection provided. Do not operate the instrument outside its rated supply voltages or environmental range. In particular excessive moisture may impair safety.

WARNING! THIS INSTRUMENT MUST BE EARTHED

Any interruption of the mains earth conductor inside or outside the instrument will make the instrument dangerous. Intentional interruption is prohibited. The protective action must not be negated by the use of an extension cord without a protective conductor.

When the instrument is connected to its supply, terminals may be live and opening the covers or removal of parts (except those to which access can be gained by hand) is likely to expose live parts. The apparatus shall be disconnected from all voltage sources before it is opened for any adjustment, replacement, maintenance or repair.

Any adjustment, maintenance and repair of the opened instrument under voltage shall be avoided as far as possible and, if inevitable, shall be carried out only by a skilled person who is aware of the hazard involved.

If the instrument is clearly defective, has been subject to mechanical damage, excessive moisture or chemical corrosion the safety protection may be impaired and the apparatus should be withdrawn from use and returned for checking and repair.

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of makeshift fuses and the short-circuiting of fuse holders is prohibited.

This instrument uses a Lithium button cell for non-volatile memory battery back-up; typical life is 5 years. In the event of replacement becoming necessary, replace only with a cell of the correct type, i.e. 3V Li/$Mn0_2$ 20mm button cell type 2032. Exhausted cells must be disposed of carefully in accordance with local regulations; do not cut open, incinerate, expose to temperatures above 60°C or attempt to recharge.

Do not wet the instrument when cleaning it and in particular use only a soft dry cloth to clean the LCD window. The following symbols are used on the instrument and in this manual:-

Caution - refer to the accompanying documentation, incorrect operation may damage the instrument.

terminal connected to chassis ground.

mains supply OFF.

mains supply ON.

alternating current.

EMC

This function generator has been designed to meet the requirements of the EMC Directive 89/336/EEC.

Compliance was demonstrated by meeting the test limits of the following standards:

Emissions

EN55011 (1991) for industrial, scientific and medical (ISM) radio-frequency equipment; Group 1 Class B limits were applied.

Immunity

EN50082-1 (1992) Generic immunity standard for residential, commercial and light industry. Test methods and limits used were:

a) EN60801-2 (1993) Electrostatic Discharge, 8 kV air discharge.

b) IEC801-3 (1984) RF Field, 3 V/m.

c) IEC801-4 (1988) Fast Transient, 1 kV peak.

Cautions

To ensure continued compliance with the EMC directive the following precautions should be observed:

a) connect the generator to other equipment using only high quality, double-screened cables.

b) after opening the case for any reason ensure that all signal and ground connections are remade correctly before replacing the cover. Always ensure all case screws are correctly refitted and tightened.

c) In the event of part replacement becoming necessary, only use components of an identical type, see the Parts List.

Installation

Check that the instrument operating voltage marked on the rear panel is suitable for the local supply. Should it be necessary to change the operating voltage, proceed as follows:

1) Disconnect the instrument from all voltage sources.

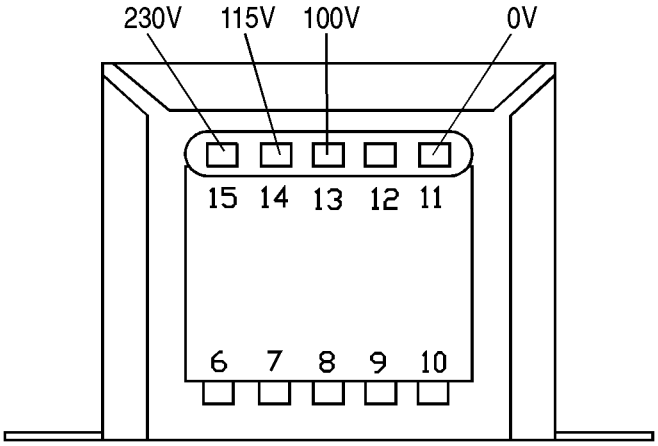
2) Remove the screws which retain the top cover and lift off the cover.

3) Change the transformer connections as follows:
   for 230V operation connect the live (brown) wire to pin 15
   for 115V operation connect the live (brown) wire to pin 14
   for 100V operation connect the live (brown) wire to pin 13.

4) Refit the cover and the secure with the same screws.

5) To comply with safety standard requirements the operating voltage marked on the rear panel must be changed to clearly show the new voltage setting.

6) Change the fuse to one of the correct rating, see below.



Fuse

Ensure that the correct mains fuse is fitted for the set operating voltage. The correct mains fuse types are:

for 230V operation:	250 mA (T) 250 V HRC
for 110V/115V operation:	500 mA (T) 250 V HRC

To replace the fuse, disconnect the mains lead from the inlet socket and release the fuse drawer below the socket pins by depressing both clips together, with miniature screwdrivers, so that the drawer can be eased open. Change the fuse and replace the drawer.

The use of makeshift fuses or the short-circuiting of the fuse holder is prohibited.

Mains Lead

When a three core mains lead with bare ends is provided it should be connected as follows:-

Brown	**-**	**Mains Live**
Blue	**-**	**Mains Neutral**
Green / Yellow	**-**	**Mains Earth**

WARNING! THIS INSTRUMENT MUST BE EARTHED

Any interruption of the mains earth conductor inside or outside the instrument will make the instrument dangerous. Intentional interruption is prohibited. The protective action must not be negated by the use of an extension cord without a protective conductor.

Mounting

This instrument is suitable both for bench use and rack mounting. It is delivered with feet for bench mounting. The front feet include a tilt mechanism for optimal panel angle.

A rack kit for mounting one or two of these Half-width 3U high units in a 19” rack is available from the Manufacturers or their overseas agents.

Service Handling Precautions

Service work or calibration should only be carried out by skilled engineers. Please note the following points before commencing work.

Most of the integrated circuits are CMOS devices and care should be taken when handling to avoid damage by static discharge.

Many of the devices are miniature surface mount components with very fine leads on small pitches; these components must be removed and replaced with great care to avoid damage to the pcb. It is essential that only tools and soldering equipment specifically designed for surface mount components are used.

The decoupling capacitors associated with the integrated circuits are surface mounted on the solder side of the pcb.

Dismantling the Instrument

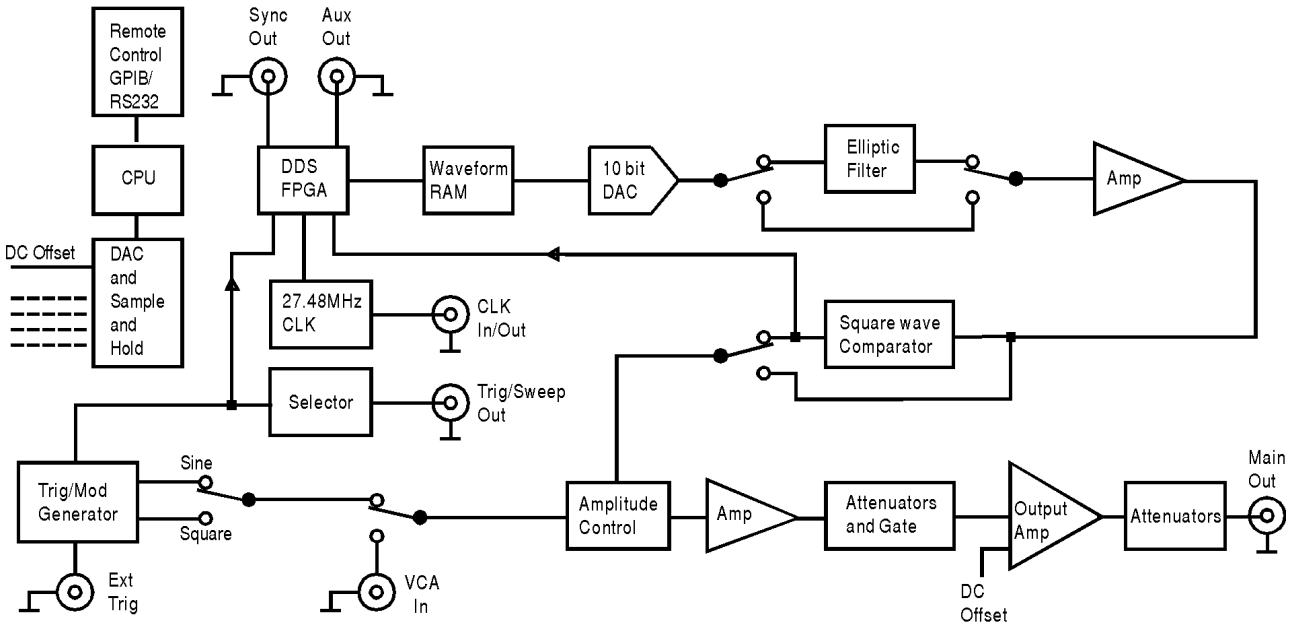
WARNING

Disconnect the instrument from all voltage sources before it is opened for adjustment or repair. If any adjustment or repair of the opened instrument is inevitable it shall be carried out only by a skilled person who is aware of the hazards involved.

1. Remove the six screws retaining the top cover.
2. The rear panel may be removed as follows. If the GPIB option is fitted disconnect the grey ribbon cable from PJ4 on the GPIB pcb. Remove the jackscrews which secure the RS232 connector to the rear panel. Invert the instrument and remove the three screws securing the rear panel; the panel may now be tilted back to allow access. If the panel is to be completely removed unplug connectors from PJ4, PJ7 & PJ8 and the blue and brown wires from the mains inlet filter; desolder the blue and brown wires from the mains transformer. The panel can now be lifted free of the instrument.
3. The front panel assembly may be removed as follows. Unplug the connectors from PJ2, PJ3, PJ5 & PJ6 and desolder the screened cable from PJ10. Remove the nut securing the front panel earthing strap and the four nuts securing the front panel assembly. The panel may now be drawn clear of the instrument.
4. Main pcb removal. Remove all connectors from the pcb and desolder the screened cable from PJ10. Tilt the rear panel back as described in 2 above. Remove the pcb fixing screw nearest PJ10; invert the instrument and remove the 5 screws retaining the pcb fixing pillars to the case lower. The main pcb can now be lifted free, complete with its fixing pillars.
5. When re-assembling the instrument ensure that all fixings use the correct fastenings.

General

The following sections should be read with reference to the block diagram and the circuit diagrams.



Simplified Block Diagram

DDS Principles

In this instrument waveforms are generated by Direct Digital Synthesis (DDS). One complete cycle of the waveform is stored in RAM as 1024 10-bit amplitude values. As the RAM address is incremented, the waveform values are output to a Digital-to-Analogue Converter (DAC) which reconstructs the waveform. Sinewaves and triangles are subsequently filtered to smooth the steps in the DAC output. The frequency of the waveform is determined by the rate at which the RAM addresses are changed. Further details of how this rate is varied, i.e. how the frequency is changed, are given later in the DDS Operation section; it is sufficient to know that at low frequencies the addresses are output sequentially but at higher frequencies the addresses are sampled. The major advantages of DDS over conventional analogue generation are:

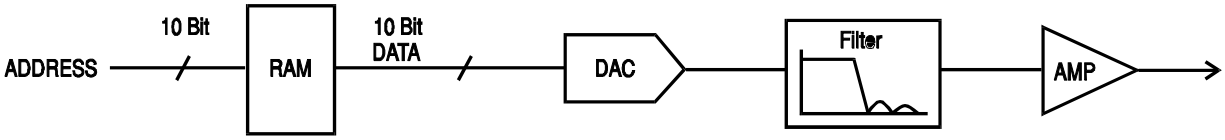
- Frequency accuracy and stability is that of the crystal oscillator.
- Frequencies can be set with high resolution from mHz to MHz.
- Low phase noise and distortion.
- Very wide frequency sweeps are possible.
- Fast phase continuous frequency switching.
- Non-standard waveforms such as multi-level squarewaves are easily generated.
- Basic arbitrary waveform capability in the same instrument.

In addition, being a digital technique, it is easier to make every parameter programmable from the keyboard, or remotely via RS232 or GPIB interfaces.

The fundamental limitation of the DDS technique is that, as the generator frequency is increased, each waveform cycle is constituted from fewer samples. This is not a problem with sinewaves which, because they are filtered, can be produced with low distortion up to the frequency limit of the generator. With DDS squarewaves and pulse waveforms the 1 clock edge uncertainty sets a practical limit to the upper frequency. However, on this instrument the generation technique changes at 30kHz (but is overridable by the user) to use a comparator driven by the DDS

sinewave; this ensures jitter-free squarewaves and pulses up to the frequency limit of the generator. Ramp and staircase waveforms are by default, unfiltered (although filtering can be selected) and therefore become degraded above the frequencies indicated in the Specification; all waveforms are, however, available up to the maximum frequency of the generator.

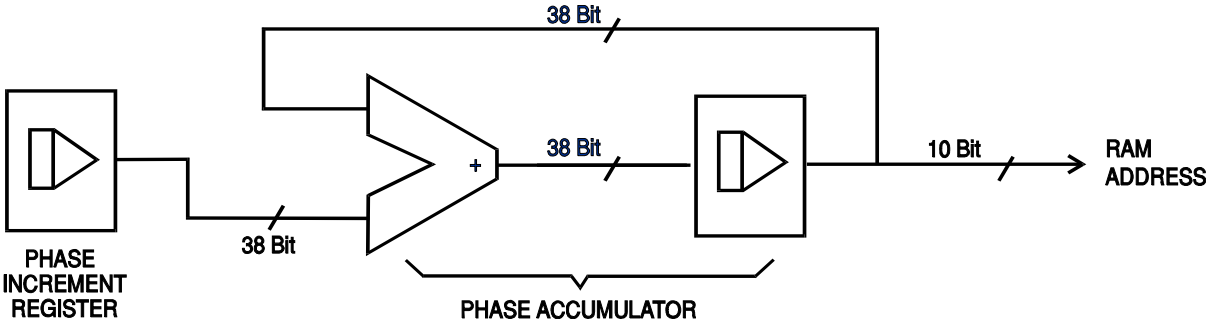
DDS Operation



One complete cycle of the selected waveform is stored in RAM as 1024 10-bit amplitude values. As the RAM address is incremented the waveform values are output sequentially to a Digital-to-Analogue Converter (DAC) which reconstructs the waveform as a series of voltage steps. Sinewaves and triangles are subsequently filtered to smooth the steps in the DAC output.

The frequency of the output waveform is determined by the rate at which the RAM addresses are changed; in a DDS system the address changes are generated as follows.

The RAM contains the amplitude values of all the individual points of 1 cycle (360°) of the waveform; each sequential address change corresponds to a phase increment of the waveform of 360°/1024. Instead of using a counter to generate sequential RAM addresses, a **phase accumulator** is used to increment the phase.



On each clock cycle the phase increment, which has been loaded into the **phase increment register** by the CPU, is added to the current result in the phase accumulator; the 10 most significant bits of the phase accumulator drive the RAM address lines. The output waveform frequency is now determined by the size of the phase increment at each clock. If each increment is the same size then the output frequency is constant; if it changes, the output frequency changes but with phase continuity.

The generator uses a 38-bit accumulator and a clock frequency which is $2^{38} \times 10^{-4}$ (~27·487MHz); this yields a frequency resolution (corresponding to the smallest phase increment) of $f_{CLK}/2^{38}$ = 0·1mHz.

Only the 10 most significant bits of the phase accumulator are used to address the RAM. At a waveform frequency of $f_{CLK}/1024$ (~26·84kHz), the 'natural' frequency, the RAM address increments on every clock. At all frequencies below this (i.e. at smaller phase increments) one or more addresses are output for more than one clock period because the phase increment is not big enough to step the address at every clock. Similarly at waveform frequencies above the natural frequency the larger phase increment causes some addresses to be skipped, giving the effect of the stored waveform being 'sampled'; different points will be sampled on successive cycles of the waveform. The minimum number of points required to accurately reproduce a waveshape will determine the maximum useful output frequency:

$$f_{max} = f_{CLK}/\text{No. of points}$$

For sinewaves the filter permits the waveform to be reproduced accurately up to the Nyquist limit ($f_{CLK}/2$), although in this generator a practical limit of 10MHz is set.

MPU and Memory

The majority of the digital hardware in the instrument is contained in 3 LSI devices, these being a MicroProcessor Unit, IC36, and 2 Field Programmable Gate Arrays, IC41 and IC44.

The Z80180 MPU contains an 8 bit Z80 core, 2x16 bit counter-timers, 2x8 bit serial interfaces and a memory management unit. The MPU is clocked at 12MHz by XTL1.

The MPU provides up to 20 memory address lines but only the lower 18 are used to provide access to 256k bytes of memory This comprising a 256k byte EPROM, IC38, with the top 32k bytes overlaid by SRAM, IC39. The MPU selects between the memory devices via a decoder located in the FPGA at IC44.

The RS232 interface is provided directly by the MPU and is buffered to the rear panel connector, PJ1, by IC34 and IC35.

One of the counter-timers provides a constant 125us 'tick' to the MPU which is used to time all the housekeeping functions, e.g. keyboard scan, knob control, as well as some generator functions, e.g. frequency sweep. The second counter-timer is used by the Trigger generator.

Keyboard, LCD and Leds

The keyboard is interrogated every 10ms. This is done by reading the registers in IC19 and IC45. If a key is down then one of the transistors Q15-Q20 will be on and the corresponding bits read from IC19/IC45 will be high. The MPU decodes this to produce a key code which is passed to the software. Multiple keys down are ignored. IC44 provides the port decode signals for access to IC19 and IC45.

The knob is connected directly to the FPGA, IC44. This decodes the 4 states of the switches and increments/decrements a counter. The counter is read and cleared every 10ms and the value and sign passed to the software.

The 16 leds are driven directly from the latches in the shift registers IC14 and IC15. These latches are updated as required via the FPGA, IC44.

The LCD is accessed via a bi-directional 4 bit port in IC44

GPIB

The FPGA, IC44, provides the port select signals to the GPIB board if fitted. The software automatically detects the presence of the GPIB board at power up and allows the user to select it on the I/F menu.

DDS FPGA

The FPGA, IC41, provides the complete DDS system including 38-bit phase accumulator, two 38-bit registers to hold the frequency values for FSK, trigger/gate control logic, 10-bit re-loadable burst counter, multi-instrument phase synchronisation logic and an 8-bit 16-port bi-directional MPU interface. Access is provided to the waveform RAM to allow the patterns to be written and the AUX output signal is generated or selected.

All internal operations of the FPGA are clocked by the signal DDSCLK. Note that if this signal is interrupted it is possible for the FPGA to become non-functional requiring that the FPGA be completely reset. The clock could be interrupted by a fault condition or by setting the CLOCK BNC to INPUT and then providing an unacceptable clock. An unacceptable clock is any signal which overrides the internal clock but produces a replacement which is less than 5MHz or greater than 27.5MHz; one way to accidentally accomplish this is to connect a 50Ω pad across the clock input.

Pseudo random noise may also be generated by the FPGA. Each time the user turns noise ON or OFF the FPGA is re-programmed to the required function. Note that this also has the effect of completely resetting the FPGA.

Trigger Generator

This is created from the second counter-timer in the MPU and a programmable divide by 1/10/100/1000 counter in the FPGA, IC44. The counter-timer produces a squarewave in the range 50kHz to 5Hz and the divider extends this to 0.005Hz.

Waveform DAC and filter

IC1 is a high speed 10-bit DAC whose data is latched on the rising edge of the clock. The DAC output is 1Vp-p and is referred to the +5VA rail. IC1 has an internal 2V reference at pin 16 referred to +5VA.

L3, L4, L5 and associated components form a 7-stage elliptic filter with sinx/x correction. The inductors L3,L4 and L5 are factory preset before manufacture and must not be adjusted. Relay RL1 allows the filter to be switched in and out.

Amplifier and Level Shift

IC7 is a current feedback amplifier. The output of IC7 is approximately 4Vp-p and is centred around 0VA. IC11C selects the waveform source and IC11A selects low pass filter R3/C17 when in noise mode.

High Frequency Squarewaves

Low frequency squarewaves are generated via the RAM and DAC, high frequency squarewaves are generated by converting the sinewave to square with comparator IC6. Adjusting the comparator threshold varies high frequency symmetry. The comparator output drives IC4 which gives squarewaves above, below or about 0VA.

Amplitude Control and Modulation

IC2 is a 4-quadrant multiplier. Amplitude is voltage controlled via IC8A. AM is selected by IC11B and IC25C. The internal squarewave modulation source is generated by IC25B; the amplitude is adjusted by varying the levels that IC25B switches between. The internal sinewave modulation source is fixed at 1kHz and is achieved by passing the output of IC25B through a Sallen and Key low pass filter. The current output of IC2 is converted to a voltage by R44 giving approximately 900mVp-p at maximum output. IC46 amplifies this to give approximately 3.6Vp-p.

Output Amplifier and Attenuators

IC3 is an intermediate switched attenuator giving 0dB, -12dB and -20dB. IC10 is a current feedback amplifier with a gain of approximately 5.5 and gives 20Vp-p at maximum output. DC offset control is via R33 and IC8B. Relays RL2 and RL3 select -20dB 50Ω attenuators. Relay RL4 selects 50 or 600 Ω output impedance and RL5 output on/off.

DAC and Sample and Holds

IC18 is a 12-bit serial DAC with internal 2V reference. IC31 provides a bipolar output. IC20 multiplexes the DAC output voltage onto the appropriate hold capacitor. FET input amplifiers IC12 and IC24 buffer the voltages on the hold capacitors. The voltage at each sample and hold is controlled by the MCU which calculates each value from a combination of the instrument set up and the calibration constants stored in EEPROM.

Power Supply

The transformer has two separate secondaries, one for the digital supply the other for the analogue supplies. The digital 5V is supplied by low drop-out regulator IC27. The display backlight current is sourced from the unregulated side of IC27. The backlight current is controlled by a 200mA current source Q8/IC26A. IC28 and IC29 provide the analogue +/-15V rails and IC30 the -5V. IC5 provides local regulation for the waveform DAC IC1. Digital and analogue grounds join at the waveform DAC IC1. PJ11 is a test point for the supply rails. Three PCB mounted fuses protect the transformer secondaries under fault conditions.

Required values measured at PJ11:

pin 1: +15V +/-0.6V

pin 5: -15V +/-0.6V

pin 2: +5VA +/-0.2V

pin 6: +5VCPU +/-0.2V

pin 4: -5VA +/-0.2V

All parameters can be calibrated without opening the case, i.e. the generator offers 'closed-box' calibration. All adjustments are made digitally with calibration constants stored in EEPROM. The calibration routine requires only a DVM and a frequency counter and takes no more than a few minutes.

The crystal in the timebase is pre-aged but a further ageing of up to ± 5ppm can occur in the first year. Since the ageing rate decreases exponentially with time it is an advantage to recalibrate after the first 6 month's use. Apart from this it is unlikely that any other parameters will need adjustment.

Calibration should be carried out only after the generator has been operating for at least an hour in normal ambient conditions.

Equipment Required

- 3½ digit DVM with 0·25% DC accuracy and 0·5% AC accuracy at 1kHz.
- Frequency counter capable of measuring 10·00000MHz and 50µs ±0·1µs pulsewidths.

The DVM is connected to the MAIN OUT and the counter to the AUX OUT.

Frequency meter accuracy will determine the accuracy of the generator's clock setting and should ideally be ±1ppm.

It may be quicker to use an oscilloscope for steps 05 and 15 (see next section).

Calibration Procedure

The CALibration procedure is accessed by pressing the blue EDIT key followed by CAL, the shifted function of 6. At each step the display changes to prompt the user to adjust the rotary control or FIELD/DIGIT keys, until the reading on the specified instrument is at the value given. The FIELD keys provide very coarse adjustment, the DIGIT keys coarse adjustment and the rotary control fine adjustment. Pressing CONFIRM increments the procedure to the next step; pressing CE decrements back to the previous step. Alternatively, pressing ESCAPE exits to the last CAL display at which the user can choose to either keep the new calibration values (CONFIRM), return to the old values (ESCAPE) or restart the calibration procedure (CE).

The first two displays (CAL 00 and CAL 01) specify the connections and adjustment method. The subsequent displays, CAL 02 to CAL 20, permit all adjustable parameters to be calibrated.

The full procedure is listed below; the name of the control signal being adjusted at each step and the default DAC value are shown in brackets. The display itself shows a summary of the step adjustment procedure and the actual DAC value.

CAL 02	Output DC offset zero; adjust for 0V ± 5mV (DCOFFSET, 2060).
CAL 03	Output DC offset +ve full scale; adjust for 10V ± 20mV (DCOFFSET, 4000).
CAL 04	Output DC offset -ve full scale; check for -10V ± 20mV (DCOFFSET, 0120).
CAL 05	Multiplier control zero offset; adjust for minimum output (AMPL, 2060).
CAL 06	HF squarewave, IC4 grounded; note offset.
CAL 07	Waveform DAC at mid-scale; adjust for CAL06 value ± 10mV (WAVOFST, 1820).
CAL 08	Waveform DC offset; adjust for 0V ± 5mV (DCOFFSET, 2058).
CAL 09	Waveform DAC at full scale; adjust for 10V ± 10mV (AMPL, 0300).
CAL 10	HF squarewave full scale; adjust for 10V ± 10mV (SQLEVEL, 1100).
CAL 11	-20dB output attenuator; adjust for 1V ± 1mV (AMPL, 4000).

CAL 12	-40dB output attenuator; adjust for 0·1V ± 0·1mV (AMPL, 4000).
CAL 13	-12dB intermediate attenuator; adjust for 1·768VAC ± 5mV (AMPL, 0300).
CAL 14	-20dB intermediate attenuator; adjust for 0·707VAC ± 1mV (AMPL, 0300).
CAL 15	AM squarewave zero; adjust for minimum output, (+AMSQ, 2050).
CAL 16	AM squarewave full scale; adjust for 10V ± 10mV (+AMSQ, 1000).
CAL 17	AM sinewave full scale; adjust for 3·54VAC ± 10mV (+AMSQ, 0650). Check for a good sinewave on the scope.
CAL 18	HF squarewave symmetry (50%); adjust for 50us ± 0·1us (SYM, 2060).
CAL 19	HF squarewave symmetry (75%); adjust for 75us ± 0·1us (SYM, 2741).
CAL 20	Clock calibrate. 10MHz at main and aux outputs or 27·48779MHz at clock in/out when set as an output; adjust to ±1ppm. Fail if outside these limits. 300-3700 shown on the display (2000).

Press CONFIRM twice to store new values and exit calibration mode.

Each adjustment step allows the MCU to calculate a calibration constant which is stored in EEPROM. Because each step allows a very wide adjustment range it is possible to stop the instrument functioning completely; if this is suspected the default values listed above should be set and a complete recalibration should then be performed.

When CAL is first entered and the confirmation screen is displayed, pressing the CE key will invoke a set of hardware tests. Follow the on-screen prompts to execute these tests. Note: The RAM test will not function correctly if SWEEP is active when CAL is entered.

PCB ASSY MAIN - TG1010 (44912-0270)

Part Number	Description	Position
20234-0011	SCREW M3 X 10 PNHDPZ NPST	FOR PJ1
20613-9401	WASHER TO220 ADHESIVE	FOR SK1-4
20670-0130	HEATSINK PCB MTG 25MM HIGH	SK1
20670-0135	CLIP GP02 FOR PCB MTG H/SINKS	FOR SK1-4
20670-0200	HEATSINK PCB MTG 50MM HIGH	SK2,3,4
20670-9002	T0220 CLIP ON HEATSINK	FOR Q8
22010-0610	BATTERY 3V LITH 20MM BUTTON	BATT
22040-0901	BEAD FERRITE FX1115	FB1-6
22042-0181	INDUCTOR 4.3UH	L5
22042-0182	INDUCTOR 4.8UH	L4
22042-0183	INDUCTOR 5.0UH	L3
22160-0002	CHOKE 1 AMP VHF SUPP	L1
22240-0020	RELAY TYPE 53/5 (24V)	RL1,2,3
22240-0050	RELAY TYPE 47 (24VDC)	RL4,5
22315-0450	FUSE 500mAT SUBMIN PCB MNT	FS1,3
22315-0453	FUSE 1.5AT SUBMIN PCB MNT	FS2
22469-0203	VERO PIN 18-0223K	FOR PJ10
22573-0041	HEADER 2 WAY STRAIGHT	LK1,2
22573-0202	HEADER 2 WAY STRAIGHT .156P	PJ5,8,9
22573-0205	HEADER 5 WAY STRAIGHT .156P	PJ7
22573-0206	HEADER 6 WAY STRAIGHT .156P	PJ4
22574-0400	SKT 9W R/A D-TYPE (RS232)	PJ1
22575-0009	SHORTING BLOCK RED	FOR BATTERY
22575-0038	HEADER 6 WAY STR 0.1P	PJ11
22575-0065	HEADER 20 WAY (2X10) STR SKELN	PJ6
22575-0066	HEADER 40 WAY (2X20) STR SKELN	PJ2
22575-0100	HEADER 34 WAY (2X17) STR SKELN	PJ3
23185-0000	RES ZERO OHM	R58
23202-0100	RES 10R0F W25 MF 50PPM	R121,147
23202-0102	RES 10R2F W25 MF 50PPM	R53,56
23202-0360	RES 36R0F W25 MF 50PPM	R37,40,185
23202-0470	RES 47R0F W25 MF 50PPM	R23,32
23202-0560	RES 56R0F W25 MF 50PPM	R39
23202-0680	RES 68R0F W25 MF 50PPM	R36

PCB Assy Main - TG1010 (44912-0270) continued/...

Part Number	Description	Position
23202-1100	RES 100RF W25 MF 50PPM	R2,22,24,45,46,81,82,103,165,167,186
23202-1120	RES 120RF W25 MF 50PPM	R85,86,87,88,90,91,97,98,99,159
23202-1150	RES 150RF W25 MF 50PPM	R67
23202-1220	RES 220RF W25 MF 50PPM	R3,113,176
23202-1270	RES 270RF W25 MF 50PPM	R38,168,169,170
23202-1330	RES 330RF W25 MF 50PPM	R16,62
23202-1360	RES 360RF W25 MF 50PPM	R149
23202-1470	RES 470RF W25 MF 50PPM	R44,63,65
23202-1510	RES 510RF W25 MF 50PPM	R31,33
23202-1549	RES 549RF W25 MF 50PPM	R57
23202-1680	RES 680RF W25 MF 50PPM	R21,71,77,89,93,134-140,175
23202-1750	RES 750RF W25 MF 50PPM	R15
23202-2100	RES 1K00F W25 MF 50PPM	R4-13,61,83,120,152,153,156-158, 163,173,174
23202-2137	RES 1K37F W25 MF 50PPM	R142
23202-2150	RES 1K50F W25 MF 50PPM	R66
23202-2200	RES 2K00F W25 MF 50PPM	R68,164
23202-2270	RES 2K70F W25 MF 50PPM	R184
23202-2330	RES 3K30F W25 MF 50PPM	R35,116,179
23202-2470	RES 4K70F W25 MF 50PPM	R34,70,72,73,74,75,154,155,162, 166,172, 177,178
23202-2820	RES 8K20F W25 MF 50PPM	R60
23202-2910	RES 9K10F W25 MF 50PPM	R130
23202-3100	RES 10K0F W25 MF 50PPM	R59,80,84,101,102,106-109,111,112, 114,115,123,124,127,129,143,180,181
23202-3120	RES 12K0F W25 MF 50PPM	R17,20,25,27,28
23202-3180	RES 18K0F W25 MF 50PPM	R148
23202-3200	RES 20K0F W25 MF 50PPM	R132,160,161,171
23202-3270	RES 27K0F W25 MF 50PPM	R144,150
23202-3330	RES 33K0F W25 MF 50PPM	R151
23202-3430	RES 43K0F W25 MF 50PPM	R133
23202-3470	RES 47K0F W25 MF 50PPM	R117,118,146
23202-4100	RES 100KF W25 MF 50PPM	R14,92,104,110,125
23202-5100	RES 1M00F W25 MF 50PPM	R105
23206-0033	RES 3R3F W60 MF 100PPM MRS25	R141
23206-0412	RES 41R2F W60 MF 50PPM MRS25	R51,52,54,55
23206-1200	RES 200RF W60 MF 50PPM MRS25	R47,48,49,50

PCB Assy Main - TG1010 (44912-0270) continued/...

Part Number	Description	Position
23206-6100	RES 10M0F W60 MF 50PPM MRS25	R126,128
23222-0047	RES 4R7J W33 MF FUSIBLE NFR25	R29,30,76,95,96,145
23301-0435	RES NETWK SIL 1K0 X 5	RP1,2
23301-0443	RES NETWK SIL 22K X 8	RP3,4,5
23427-0268	CAP 22PG 100V CER NPO P2.5	C10,39,45-48,64,103,104
23427-0325	CAP 10NZ 63V CER HI K P5	C73-75,81-84,92-95,99,121,136,138
23427-0357	CAP 33PG 63V CER N150 P2.5	C21,32,101
23427-0374	CAP 100PG 100V CER N150 P2.5	C16,20,62
23427-0385	CAP 39PG 100V CER N150 P2.5	C22,90
23427-9205	CAP 47PG 100V CER NPO P2.5	C14,98,149
23427-9206	CAP 15PG 100V CER NPO P2.5	C63,91
23427-9210	CAP 3P3C 100V CER NPO P2.5	C38
23427-9218	CAP 330PK 100V CER MED K P2.5	C61
23427-9221	CAP 12PG 100V CER NPO P2.5	C15,18
23461-0020	CAP SM0805 100NZ 50V CER Y5V	SC1-37
23557-0530	CAP 100U 16V ELEC RC2 P2.5	C87
23557-0550	CAP 10U 16V ELEC BIPOLAR P2	C29,56,57,58,148
23557-0612	CAP 1U0 50V ELEC RE2 P2	C105
23557-0647	CAP 10U 35V ELEC RE2 P2	C1-9,33,34,78,79,80,89,119,120,135
23557-0664	CAP 1000U 35V ELEC RE2 P5	C76,77
23557-0673	CAP 22U 35V ELEC RE2 P2	C102
23557-9122	CAP 4700U 16V ELEC RE2 P7.5	C85
23620-0236	CAP 1N0K 100V P/E 435/1 P5	C17
23620-0242	CAP 22NJ 100V 5% P/E P5	C59
23620-0246	CAP 100NK 63V P/E P5	C11-13,24-28,35-37,41-44,49,52-54,60, 72,88,96,97,117,118,124,127,131,132, 134,137
23620-0249	CAP 330NK 63V P/E P5	C65-71,147
25021-0901	DIO 1N4148 B/R	D3,5,6,8-13,24-26
25061-0200	LED - T1 ROUND (3mm) - RED	LED1
25115-0907	DIO 1N4002 B/R	D14-21
25130-0903	DIO ZEN 5V1 W4	D1,2
25131-0224	DIO ZEN 18V 1W3	D22,23
25131-0226	DIO ZEN 6V2 1W3	D27
25174-0219	DIO VARICAP BB809	D4
25336-5590	TRAN PNP BC559C	Q10,15-20
25341-0214	TRAN PNP ZTX214L/BC559	Q12

PCB Assy Main - TG1010 (44912-0270) continued/...

Part Number	Description	Position
25380-0229	TRAN NPN BC549	Q3-7,11,13,14
25380-0230	TRAN NPN MPS2369	Q9
25386-9300	TRAN TIP31A	Q8
27103-0040	IC NE529N14 PIN	IC6
27106-0513	IC LM358N 8 PIN	IC26
27106-0517	IC NE5532N8 PIN	IC8
27106-0606	IC TL072CP8 PIN	IC31
27106-0628	IC TL074 14 PIN	IC9,12,24
27106-0633	IC EL2099CT 5 PIN TO-220	IC10
27106-0634	IC 2020 8 PIN	IC7,46
27151-1000	IC SM HA9P2557-9	IC2
27153-0080	IC LTC1257CN88 PIN	IC18
27153-0180	IC DAC MB4076020 PIN	IC1
27160-0009	IC V/REG 7805 TO220	IC5
27160-0012	IC V/REG 79L05 TO92	IC30
27160-0013	IC V/REG 7815 TO220	IC28
27160-0020	IC V/REG 7915 TO220	IC29
27160-0440	IC V/REG LM2940CT5 TO220	IC27
27239-0000	IC SM 74HC00	IC23
27239-0140	IC SM 74HC14	IC37
27239-0320	IC SM 74HC32	IC40
27239-0510	IC SM 74HC4051	IC3,20
27239-0530	IC SM 74HC4053	IC11,25
27239-1000	IC SM 74HCT244	IC21
27239-1010	IC SM 74HCT4051	IC4
27239-2440	IC SM 74HC244	IC22
27239-3730	IC SM 74HC373	IC19,45
27253-0020	IC SM 64180	IC36
27253-0050	IC SM 14C88	IC34
27253-0060	IC SM 14C89	IC35
27256-0020	IC SM CD4094	IC14,15,16,17
27400-0130	IC 27C2001 256Kx8 EPROM 32 pin	IC38
27403-0010	IC SM 93C46 1K(64x16) EEPROM	IC13
27412-0030	IC SM XC4002A-6	IC41
27412-0040	IC SM XC2064-50	IC44
27413-0080	IC SM 8Kx8 CMOS RAM 15ns	IC42,43

PCB Assy Main - TG1010 (44912-0270) continued/...

Part Number	Description	Position
27413-0420	IC SM 32Kx8 CMOS RAM 70-120ns	IC39
28151-0010	BUZZER C & D TRANSDUCER 40TGPC	BUZZ
28500-1030	XTAL - 27.48779MHZ	XTL2
28502-0020	RESONATOR CERAMIC 12MHZ	XTL1
31331-9030	OM358 MULTIPLEXER SCREEN	S2
35555-2320	PCB - MAIN - TG1010	

PCB ASSY KEYBOARD - TG1010 (44912-0260)

Part Number	Description	Position
22224-0010	ENCODER ROTARY 36 POSITION	SW1
22226-0130	KEYSWITCH DARK BLUE	K15
22226-0140	KEYSWITCH DARK GREY	K1-14,16-43
23185-0000	RES ZERO OHM	LK1-5,8,9,R187,188
23202-1680	RES 680RF W25 MF 50PPM	R76,78,79,94,131
23382-2470	RES PS/H 5K0 CERMET MIN	VR3
25061-0200	LED - T1 ROUND (3mm) - RED	LED1-16
35515-1410	PCB - KEYBOARD - TG1010	
43171-1380	CONN ASSY 40W MAIN/KB TG1010	PJ8 TO PJ2 MAIN

FRONT PANEL ASSY - TG1010 (46912-0610)

Part Number	Description	Position
20030-0264	WASHER M2.5 ZPST	LCD
20038-9501	WASHER M3 SPRING	KEYBOARD PCB/F.PANEL
20210-0104	NUT M2.5 ZPST	LCD
20234-0027	SCREW M3 X 6 PNHDPZ ZPST	KEYBOARD PCB/F.PANEL
20234-0040	SCREW M2.5 X 12MML PNHDPZ ZPST	LCD
20612-0011	WASHER FIBRE M3	
20620-0010	CLIP - ENCODER KNOB	KNOB
22573-0056	HEADER 16 WAY STR SIL (6.8MM)	
22219-0050	SWITCH ROCKER DPST SOLDER LUGS	
22588-0004	BNC SKT BKHD 50R STANDARD	
26100-0160	LCD 20 X 4 DMC 20481 BACKLIT	
33331-3550	FRONT PANEL - TG1010	
33331-3560	OVERLAY FRONT PANEL - TG1010	
35358-0520	EARTHING STRIP - TG1010	
37151-0320	KNOB – ENCODERS	

REAR PANEL ASSY - TG1010 (46912-0600)

Part Number	Description	Position
20030-0263	WASHER M3 ZPST	MAINS INLET
20030-0266	WASHER M4 ZPST	TRANSFORMER, EARTH
20037-0401	SOLDER TAG SHAKEPROOF - 4BA	EARTH
20038-9501	WASHER M3 SPRING	MAINS INLET
20038-9502	WASHER M4 SPRING	TRANSFORMER, EARTH
20210-0101	NUT M3 ZPST	MAINS INLET
20210-0102	NUT M4 ZPST	TRANSFORMER, EARTH
20213-0010	CAPTIVE NUT SNU-1219-17-00	
20223-9001	SCREW M3 X 8 RAISED CKHDPZ	MAINS INLET
20234-0032	SCREW M4 X 25 PNHDPZ ZPST	TRANSFORMER
20236-0010	SCREW M4 X 12 TAMPERPROOF	EARTH
20661-0272	SPACER RND 21mmIDx15.8mmL NYL	TRANSFORMER
22115-0280	TRANSFORMER - TG1010	
22520-0170	FILTER - IEC INLET + FUSE	
22588-0004	BNC SKT BKHD 50R STANDARD	
33331-3570	REAR PANEL PRINTED - TG1010	

CASED PARTS - TG1010 (59120-0801)

Part Number	Description	Position
20030-0263	WASHER M3 ZPST	CHASSIS/EARTH STRIP
20030-0266	WASHER M4 ZPST	FEET, BLANKING PLATE
20037-0301	WASHER M3 SHK/PROOF I/T ZPST	CHASSIS/FRONT PANEL
20038-9501	WASHER M3 SPRING	CHASSIS/SPACERS, PCB/SPACERS, CHASSIS/EARTH STRIP
20038-9502	WASHER M4 Spring	BLANKING PLATE
20062-0700	SCREW NO 6 X 3/8 RFLNGPZ ST/AB	CHASSIS/REAR PANEL
20063-0010	SCREW NO6 X 3/8 NIB HDPZ ST/AB	CASE UPPER
20210-0101	NUT M3 ZPST	FRONT PANEL, EARTH STRIP
20210-0102	NUT M4 ZPST	BLANKING PLATE
20213-0010	CAPTIVE NUT SNU-1219-17-00	CHASSIS
20234-0012	SCREW M3 X 8 PNHDPZ ZPST	EARTH STRIP/CHASSIS
20234-0027	SCREW M3 X 6 PNHDPZ ZPST	CHASSIS/SPACERS, PCB/SPACERS
20234-0028	SCREW M4 X 10 PNHDPZ ZPST	BLANKING PLATE
20234-0029	SCREW M4 X 12 PNHDPZ ZPST	FEET
20612-0011	WASHER FIBRE M3	PCB/SPACERS
20661-0219	SPACER Hex M3 x 15 NPBR	

Cased Parts TG1010 (59120-0801) continued/...

Part Number	Description	Position
20662-0201	BRACKET PLAS FOOT 3786-7001	
20662-0520	FOOT PVC PV2629 BLACK	
22315-0232	FUSE 250MA TL HRC S/F	UK/EURO
22315-0233	FUSE 500MA TL HRC S/F	USA
22491-0010	MAINS LEAD	UK
22491-0020	MAINS LEAD	EUROPE
22491-0040	MAINS LEAD	USA
22575-0202	SKT 2W .156 20AWG (YELLOW)IDT	PJ5,8,9 ON MAIN
22575-0205	SKT 5W .156 20AWG (YELLOW)IDT	PJ7 ON MAIN
22575-0206	SKT 6W .156 20AWG (YELLOW)IDT	PJ4 ON MAIN
31334-0110	BLANKING PIECE - 24W `IEEE'	REAR PANEL
31711-0080	BEZEL HALF RACK - 3U CASE	
33171-0130	SPRING FOOT	
33537-0720	CASE UPPER - TG1010	
33537-0730	CASE LOWER - TG1010	
43171-1390	CONN ASSY 34W MAIN/DISPLAY	
43171-1400	CONN ASSY 2W 270MM TG1010	
48591-0440	INSTRUCTION BOOK - TG1010	

PCB ASSY GPIB - TG1010 (44912-0250)

Part No.	Description	Position
20234-0011	SCREW M3 X 10 PNHDPZ NPST	J5/PCB
22574-0430	SKT 24W R/A IEEE	J5
22575-0065	HEADER 20W (2X10) STRAIGHT	J4
23620-0246	CAP 100NK 63V P/E P5	52-54,122,123
27163-1600	IC 75160	C32
27163-1620	IC 75162	C31
27250-0410	IC UPD7210C	C33
35555-2310	PCB - GPIB - TG1010	

Circuit Diagrams

ISS 5

ARC/RS232 INTERFACE

CPU AND MEMORY

I/O AND CONTROL LOGIC FPGA

DDS FPGA AND WAVEFORM LOOK-UP RAM

POWER FAIL, RESET AND BATTERY CONTROL LOGIC

KEYBOARD INTERFACE

GPIB INTERFACE PCB
44912-0259

SPARE GATES

PD25AC.CSD

TG1010 Main Pcb - Sheet 1 of 3
- Digital Section and GPIB

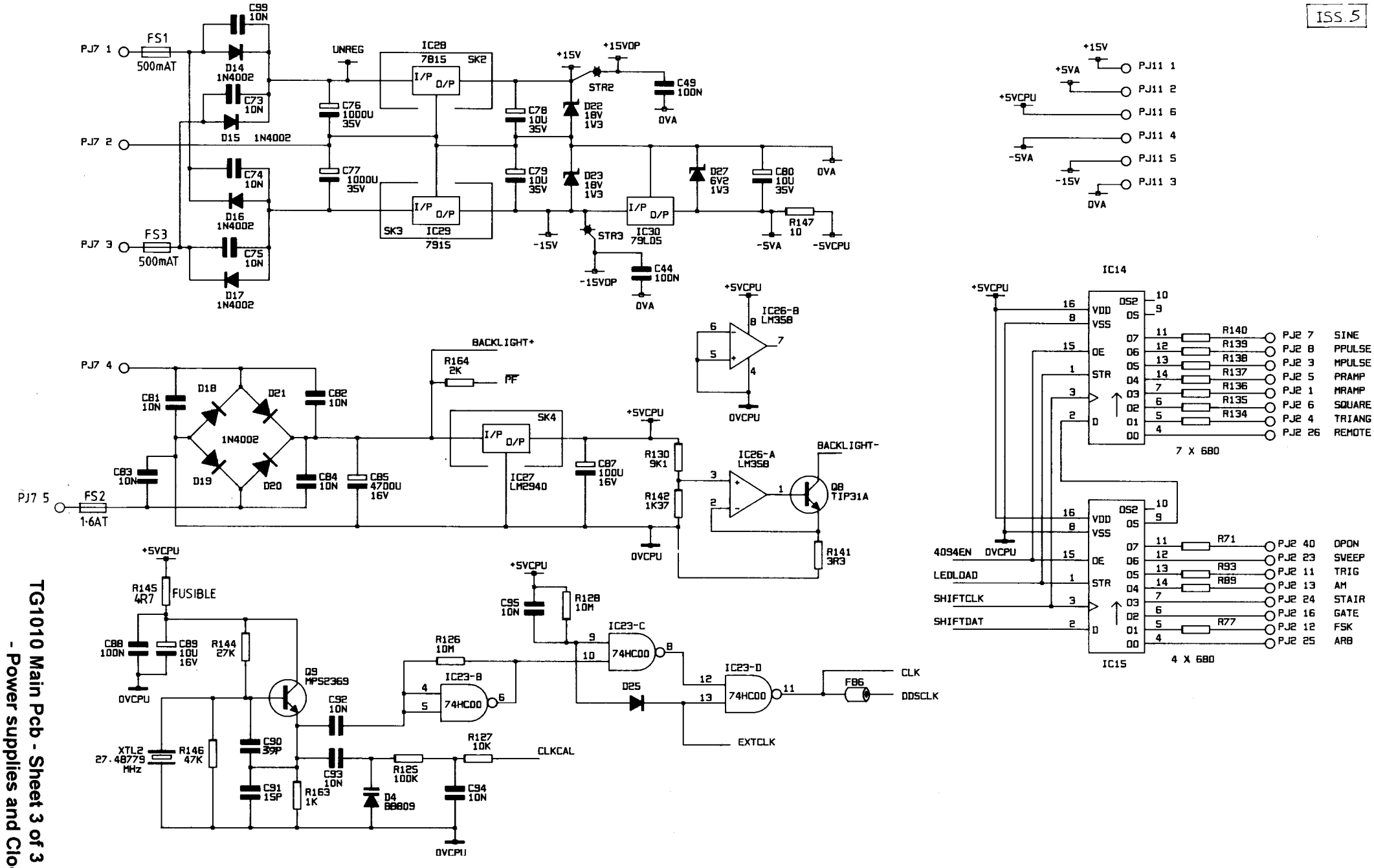
POWER SUPPLY

ISS.5

* NOT FITTED ON TG1010

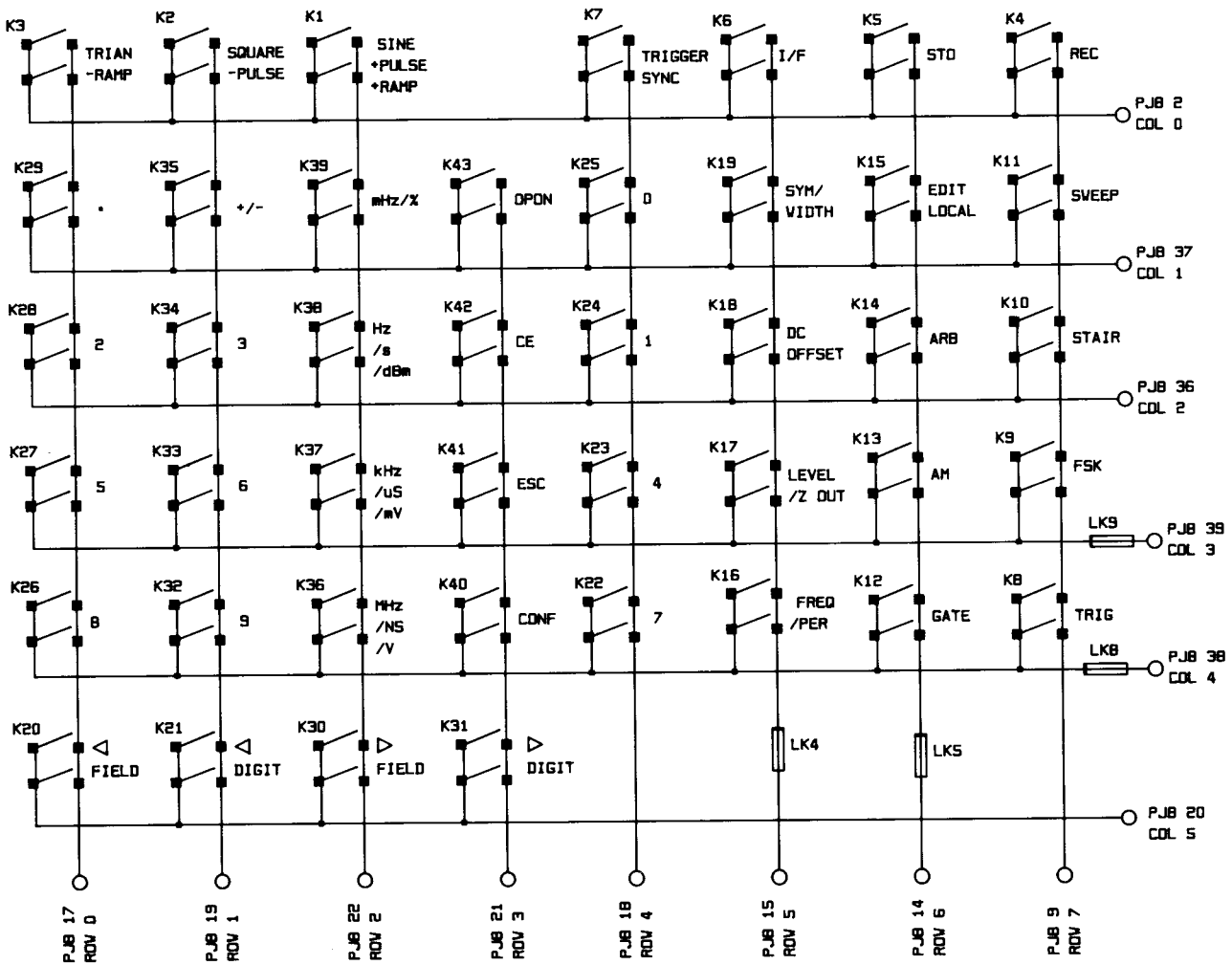
SK1 SV25-4 HSK FOR IC10

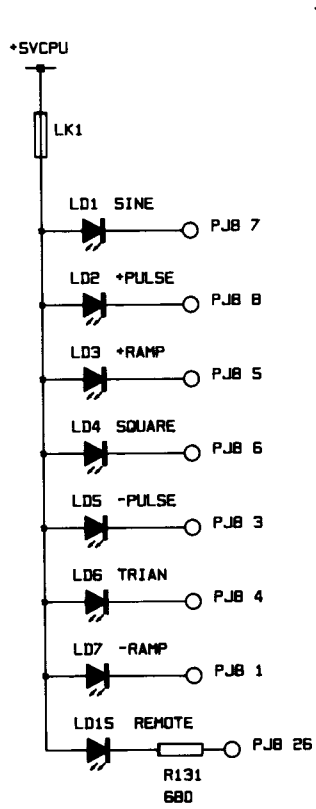
TG1010 Main Pcb - Sheet 2 of 3
- Analogue Section

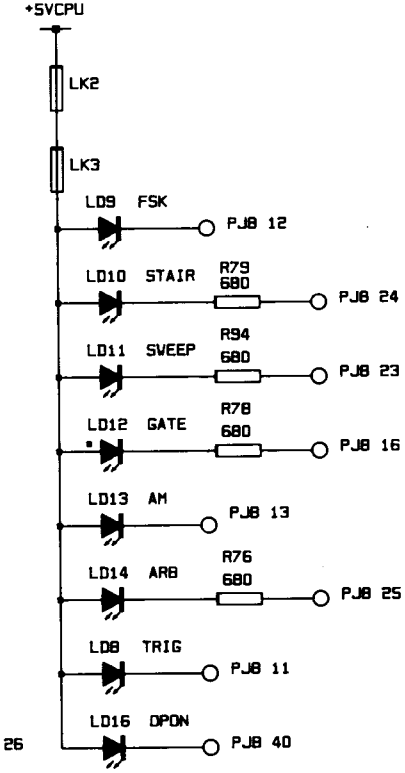


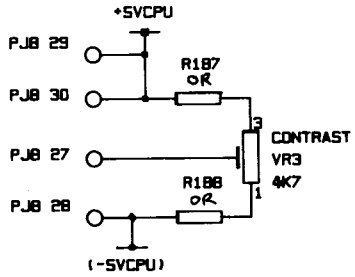
TG1010 Main Pcb - Sheet 3 of 3

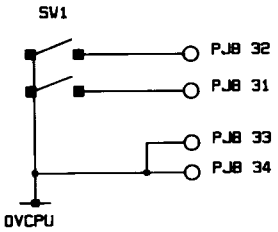
- Power supplies and Clock











TG1010 Keyboard Pcb

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