

Digital techniques—may be used with
digital plot extraction

Suitable for operation with driven and
self-oscillating transmitters

Choice of system parameters

MTI double cancellation

The Marconi Type S7100 is a signal processor used with the Marconi Type S2000 series of transmitter/receivers which are fully described in the B series of Marconi Radar Data Sheets. It utilizes digital techniques and is designed to work directly with a plot extraction system (if required) such as the Marconi Primary Radar Plot Extractor Type S7200 which is fully described in Marconi Radar Data Sheet C4. The S7100 is used with either driven or self-oscillating transmitters and provides moving target indication, clutter constant false alarm rate control, pulse recurrence frequency stagger and pulse recurrence frequency discrimination. The video outputs are moving target indication, range gated and clutter switched against a second video, with or without further processing and the second video. Both analogue and digital videos are available. A range of trigger outputs is provided to drive a complete radar system, including secondary surveillance radar. A test video generator is built in.

Mechanical Features

The processor is housed in a small, attractively styled lightweight cabinet 1.675m (5ft 6in) high by 686mm (2ft 3in) wide by 648mm (2ft 1½in) deep.

The base is a welded framework of square tubular steel sections, forming a plinth. The side and rear panels are sheet aluminium with box-folded edges. These are bolted to the base and to a top framework, with bracing members at an intermediate height, to form a strong, rigid but light cabinet. A removable top panel is fitted. All the panels are clad with polyvinylchloride, which provides much greater resistance to abrasion than normal paint finishes.

The main compartment houses two slideout frames, each formed of welded square tubular steel sections, with plain front panels. These frames may each house an S7100 processor or alternatively one S7100 and one S7200 plot extractor, or one S7100 and other processing equipment for use in a diversity system. The plinth houses the input power controls, one set for each individual frame and, if the cabinet is freestanding, a cooling fan.

The cabinet with one S7100 weighs 227kg (500lb). In styling, colour, height and depth it matches the S2000 series transmitter/receivers.

Electrical Features

The processor uses solid state devices throughout, the choice of discrete components or integrated circuits depending on efficiency and cost.

The logic elements are transistor-transistor devices chosen for speed and noise protection. The stores are static shift registers, using low-level metal oxide silicon logic compatible elements.

A modular form of construction enables a build-up of facilities to be made to suit the system requirements.

Timing

Timing for the complete processor is based on a high frequency crystal clock. In a multi-processor

environment, such as a diversity system, one clock is chosen as master.

The basic clock count is sub-divided to produce the sampling waveform for the analogue-to-digital converters. Further division produces a count which is the basic timing for the transmitter trigger. Depending on the arrangement of wired links on a plug-in board, associated circuits select appropriate pulses from the basic timing waveforms to generate regular or staggered trigger pulses for the transmitter. The mean pulse recurrence frequency (p.r.f.) and the stagger ratio can be changed simply by replacing the plug-in link board by another with suitably wired links. Under the control of the transmitter trigger, a further set of dividers produce the clock and gating waveforms for the control of the remainder of the processing circuits and the display and secondary radar trigger generator. The processor is capable also of being synchronized by an external trigger input.

Moving Target Indication System

Line matching and compression amplifiers

Signals to be processed in the moving target indication (MTI) system are obtained from the transmitter/receiver as an intermediate-frequency (i.f.) input. For optimum performance the signal/noise ratio into the detector stages must be matched to the system requirements. To achieve this a compression amplifier is used, housed in either the transmitter/receiver or the processor. If the processor is remotely sited then the signal amplitude is adjusted by a line matching amplifier. A swept gain section may be selected to apply a $\frac{1}{R}$ power law to the input signal.

Detectors

The compressed intermediate frequency signal is taken to three detectors, two phase and one linear.

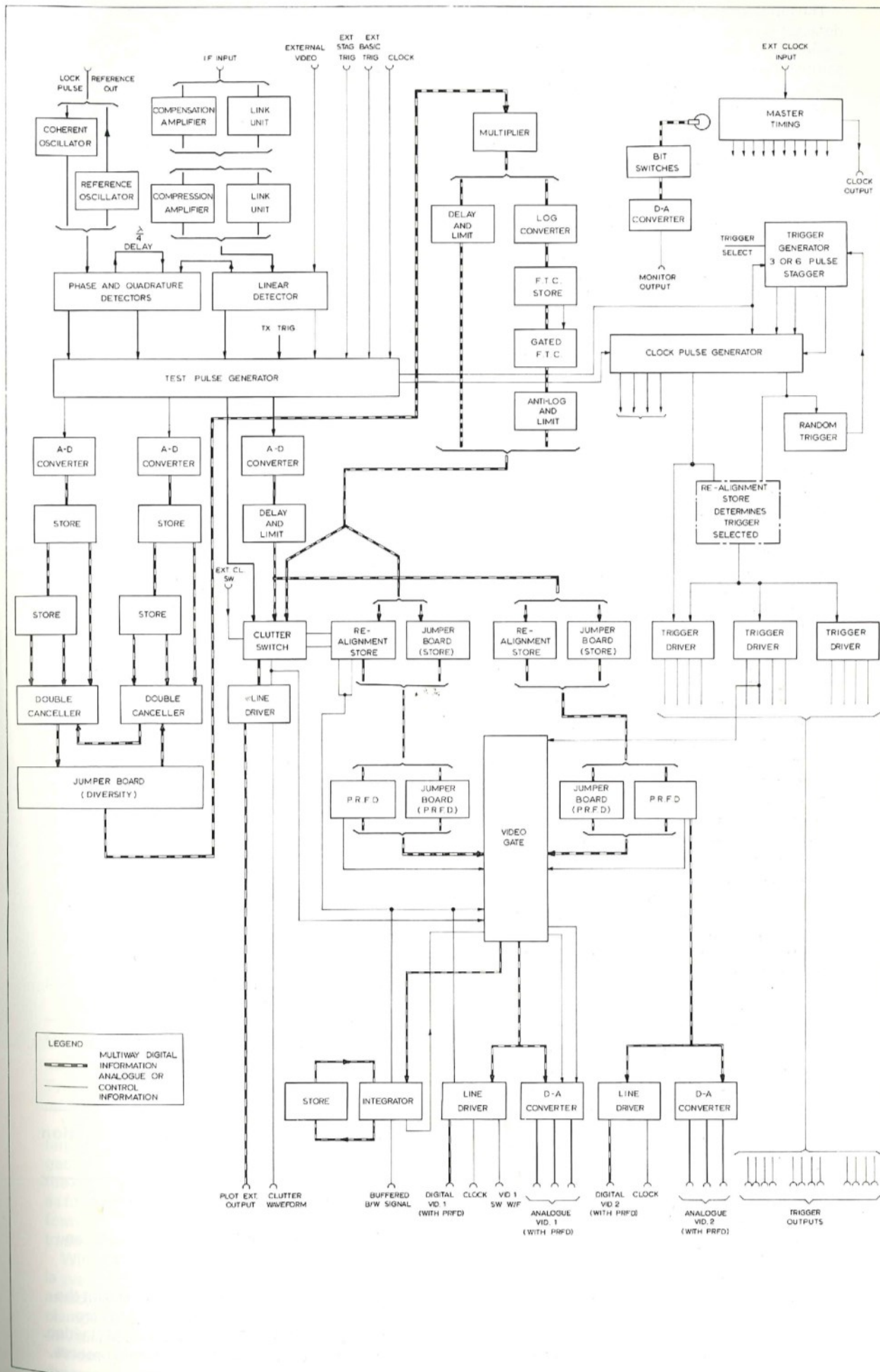
To reduce substantially the loss due to 'blind phases', that is when the absolute phase of the signal results in zero output from a single-phase detector, two phase detectors and associated filters are used. The two phase detectors are connected in parallel for the signal input but the phase of the reference to one is shifted by 90 degrees with respect to the other.

For magnetron transmitters the reference signal is generated by a coherent oscillator (COHO). This accepts a lock pulse, which is a sample of each output pulse of the magnetron converted to i.f., to determine the correct phase of the reference voltage. For driven transmitters, a reference oscillator is used.

The linear detector produces a linear video, which is used to drive the clutter switch. It may be used also as an alternative video when no external video is present.

Clutter filter

The clutter filter consists of shift register stores and a comparator circuit. Two identical channels are used for the outputs from the two phase detectors, the filtered outputs being combined to give a single video for further processing.



Block diagram for the Digital Signal Processor Type S7100

The bipolar analogue signal from the phase detector is quantized to 8-bit digital data by an analogue-to-digital converter operating at a sampling interval dependent on the transmitter pulse length. An 8-bit resolution is chosen to ensure that the filter is not a limiting factor on system performance.

Two stores in series are used, each of 1536×8 -bit capacity. At the end of each full range count, the stores hold data for that and the preceding count. At the start of the next count these two sets of data are shifted out and the new set of data shifted in. The three sets are presented to a comparator in which twice the once-delayed data is subtracted from the sum of the undelayed and twice-delayed data. Common components are reduced to noise level with little loss in general level. This method provides a satisfactory velocity response at near zero velocities without incurring excessive equipment costs.

The filtered data passes to a modulus extractor, which converts it from bipolar to unipolar form.

Combiner

The outputs of the phase and quadrature channels are passed to a simple adder to produce a single video. When the system is using frequency diversity, the output from the second signal processor is also combined at this point, full combination at this stage ensuring the best possible signal for further processing.

Scaling amplifier

In order to match the noise level to that of the second video channel, the digital video signal is scaled by adding binary fractions. An additional gating control ensures that a constant noise level output is still provided in the event of one processor of a diversity pair being switched off.

Clutter Constant False Alarm Rate Control (Clutter CFAR Control)

If the clutter filter is operated with an input signal/noise ratio such that the residue from fixed clutter is equal to normal noise level, then the residue from areas of fluctuating clutter (such as weather) is greater than normal noise level and target detectability is reduced in those areas. By following the filter with a clutter CFAR control circuit, the fluctuating clutter residue can be reduced to normal noise level and target visibility in those areas recovered.

The digital output from the scaling amplifier is first converted to a logarithmic form, in which all fluctuations are reduced to a constant level superimposed on a mean level determined by the amplitude of the fluctuations. By feeding this into a feedback integrator, with the feedback factor adjusted to match the pulse length, a correction level is obtained equal to the mean level. When this is subtracted from the logarithmic form, the residue from fluctuating clutter is significantly reduced. A gating system ensures that, in the absence of fluctuating clutter, the constant false alarm rate control is by-passed. The logarithmic output is reconverted digitally into linear form.

Pulse Recurrence Frequency Stagger (p.r.f.s.)

It is well known that the response of simple MTI falls to zero for targets flying at certain radial velocities. These velocities are referred to as blind speeds and may be calculated from the general expression :

$$V_n = \frac{n\lambda fr}{103}$$

where V_n = n^{th} blind speed in knots

λ = wavelength in cm

fr = p.r.f. in pulses per second

n = any integer

At the longest wavelength and highest p.r.f. practicable for surveillance radars, at least one blind speed still occurs within the subsonic speed range.

By operating the radar sequentially on two or more p.r.f. values, the first blind speed occurs at a much higher value. The ratio of the p.r.f. values is chosen, with due regard to the wavelength and mean p.r.f., to obtain a response which is a compromise between first blind speed and the maximum loss at intermediate points.

Whereas in the past only two or three pulse stagger was achievable, in the S7100 it is possible to use six period stagger which gives a blind speed one hundred times that due to the mean p.r.f. without excessive loss at intermediate points. Alternatively, the stagger may be random giving particular protection against impulsive spoof jamming.

The staggering of the transmitter trigger pulses is achieved simply by the selection of the appropriate pulses from the master timing chain, in a manner which ensures that full transmitter stability is maintained.

Video realignment

When associated equipment, for example some displays and plot extractors, require the input signals to arrive synchronously, additional stores are fitted which destagger, or realign, the data in the processor.

Processed data is fed into the destagger store as it becomes available, depending on the staggered transmitter trigger. Data is read out of the destagger store during the subsequent inter-pulse period under the control of a timing waveform associated with an unstaggered trigger.

Pulse Recurrence Frequency Discrimination (p.r.f.d.)

This process removes interference due to other non-synchronized radars.

The video is compared against a threshold, any crossings being passed to a one-bit store. Current incoming and delayed crossings are compared and if the former is present without the latter, then the current video is blanked to zero. The delay is three interpulse periods for MTI video, due to the pulses bred during the filtering process, and one period for other videos.

Circuits are included to allow the blanking of interference from a co-sited radar, providing a trigger pulse is available.

An important additional feature of this method of p.r.f.d., when the number of different inter-pulse periods in the staggering system exceeds the number of delays in the discriminator, is its ability to remove second-time-round returns.

Range Gate

In most systems, MTI is only required over a limited range which contains the regions of serious clutter density. Beyond this range, logarithmic or linear video is used. In the S7100, changeover is accomplished by operating a digital switch with a range gate, preset for the system environment.

Clutter Switch

Two forms of clutter switch can be provided.

In the simplest arrangement, video from the linear detector following the compression amplifier is compared against an amplitude threshold. Any crossings which exist longer than a preset time generate a gating waveform. This is used to switch in MTI video for clutter regions outside the preset range. Because the clutter circuits take time to detect the presence of clutter, the videos to be switched are delayed for this time. This switch operates against solid clutter but ceases to be effective if the clutter is broken.

In order to overcome the problem of broken clutter, a more complex form of clutter detection is employed, which divides up the radar coverage into a large number of areas. The percentage area of each sector wherein there are returns greater than a threshold, is determined by monitoring the linear video. This data, modified if necessary by data concerning the surrounding areas, determines whether or not MTI should be used in the area of interest. The clutter data is put into store until the next radar revolution, when it is used to select the correct video. The clutter switch output may be used also locally to 'ghost in' the clutter areas on a PPI display, or passed as narrow band information to a data handling system to facilitate the detection and tracking of targets.

Video Outputs

Two main types of video output are provided, referred to as Video 1 and Video 2.

Video 1 consists of a combination of moving target indication video and Video 2, the range gating and clutter switching circuits controlling the choice individually or together. This is known as fully processed video and an output in digital form, without p.r.f.d. or destaggering, is provided to drive a plot extractor.

With these two processes, applied video output is available in digital form and also converted to analogue form. The analogue video is amplified, clamped and limited to levels suitable for driving raw displays.

Video 2 may be either externally generated by the transmitter/receiver, or it may be the output

of the linear detector which follows the compression amplifier. Whichever is selected is converted to digital form for processing in stages similar to those in the moving target indication channel. This video may be used directly in either digital or analogue form or used in the production of Video 1.

The clutter switch may be used to gate, into the fully processed video, the output of a free-running oscillator, which ghosts in the clutter regions removed by the filtering process.

For Video 1, video integration is available and provides two facilities:

- 1) Generation of black/white video for driving displays.
- 2) Enhancement of fully processed video by the addition of the black/white video, to combine their advantages.

Test Facilities

A test signal generator is built in which produces video signals suitable for testing the major functions of the processor.

- 1) A ramp waveform each period passing through all 256 levels of the signal to check the clutter filter.
- 2) A similar ramp every other period to check response to moving targets.
- 3) A pulse every eighth period to check the p.r.f.d.

To enable the signals present at any point in the digital system to be monitored in analogue form, a digital-to-analogue converter is provided, with a wander lead input which may be plugged into multiway sockets provided at significant interfaces. The converter output is available to drive an oscilloscope.

Remote Controls

When switched to remote control, a 24V supply is available to be routed through the remote control panel back to the processor to switch ON or OFF the following functions:

- 1) Processor mains supply.
- 2) P.R.F.S.
- 3) Clutter CFAR.
- 4) P.R.F.D. for Video 1 channel.
- 5) P.R.F.D. for Video 2 channel.
- 6) Swept gain.
- 7) Range gate.
- 8) Clutter switch.
- 9) Ghosting.

Diversity Operation

The processor may function as one of a diversity pair, in which case the trigger generation control is assigned to one of the processors.

Data Summary

Power input:

110V or 220V or 240V $\pm 10\%$, 45 to 65Hz,
1-phase, 750VA maximum.

Pulse length (transmitter):

2 to 10 μ s.

P.R.F.:

200 to 1000 p.p.s.

Stagger ratio:

6, 4, 3, 2 periods or random.

Cancellation ratio:

greater than 40dB for the MTI system alone.

Maximum MTI range:

in excess of 120 nautical miles dependent on transmitter pulse length.

Range gate on Video 1:

10 to 60 nautical miles.

Signal Inputs*Radar i.f.***Frequency:**

45 or 44.25 MHz.

Level (noise):10 μ V minimum.**Impedance:**75 Ω .*Lock pulse***Frequency:**

45 MHz.

Level:

1.0V peak-to-peak minimum.

Impedance:75 Ω .*Logarithmic or linear video***Level (signal)**

+2.5V to +5.0V

Level (noise)

0.5V to +1.0V.

Impedance:75 Ω .**Signal Outputs***Reference frequency***Frequency:**

5.625 or 5.5312 MHz.

Level:

7.0V r.m.s. minimum.

Impedance:75 Ω .*Analogue video***Video 1, Video 2 and Video 1 integrated:**

Number of outputs: 3 per channel.

Level (noise): 0.5V to 1V r.m.s.

Level (signal): +2.5V to +5.0V.

Impedance: 75 Ω .*Digital video:***Black/white Video 1**

Level: +3V.

Impedance: 75 Ω .**Plot extractor video (non-de staggered), Video 1 and Video 2:**

Number of outputs: 1 per channel.

Level: 1.25V differential maximum.

Impedance: 150 Ω twisted pair.*Diversity video***Input:**

Level (signal and clock): 1.0V differential minimum.

Impedance: 150 Ω twisted pair.**Output:**

Level (signal and clock): 2.5V differential maximum.

Impedance: 150 Ω twisted pair.**Trigger***Outputs***Number:**

8 (an extra 4 are available if required).

Types:

basic p.r.f., undelayed: 1

basic p.r.f., delayed: 4 (additional 4 available if required)

staggered p.r.f., undelayed: 1

staggered p.r.f., delayed: 2

Amplitude:

18V minimum.

Duration:3 \pm 1 μ s.**Rise time:**

(10% to 90%) 100ns.

Impedance:75 Ω .**Delay variation:**up to 250 μ s.**Modes:**

unstaggered, 6, 4, 3, 2 pulse, random.

*Inputs***Number:**

1 for non-stagger.

2 for stagger.

Amplitude:

6V min.

Duration:2 to 40 μ s.**Impedance:**75 Ω .**Environment:****Temperature:**

Operational: 0 to +50°C

Survival: -40 to +65°C.

Relative humidity:

Operational: 95% at 25°C.

Survival: 95% at 40°C.

Pressure:

Operational: 750 mb.

Survival: 420 mb.

Dimensions (Cabinet)**Height:**

1.675m (5ft 6in).

Width:

686mm (2ft 3in).

Depth:

648mm (2ft 1 1/2in).

Weight (including one processor):

227kg (500lb).

The information given herein is subject to confirmation at the time of ordering.

Marconi Radar Systems Limited

A GEC-Marconi Electronics Company

Crompton Works, Chelmsford, England CM1 3BN

Telephone: Chelmsford (0245) 67111. Telegrams: Marstor Chelmsford Telex.

Telex: 99108 and 99449

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