# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

## RECORD



RECORD 87/63

# OMEGA TIME MARK GENERATOR

Y.S.B.LIU, B.DEVENISH and A.WARREN

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A petty patent has been applied for.

# Contents



(Circuit schematics are not included, as the commercial exploitation of the unit is being negotiated.)

## 1. Introduction

In July 1987, due to the imminent closure of Telecom's VNG Timing Service, a decision was made that the Engineering Services Unit (ESU) of the BMR should give the highest priority to the development of an Omega time mark generator ('Omega Receiver' for short) to be used as a standard time reference for BMR field installations. Seventy systems were required for portable refraction seismograph stations and fixed earthquake/nuclear monitoring installations. Other applications within BMR may include geomagnetic observatories, ground reference stations for airborne and marine surveys etc. Outside organisations such as state mines departments and universities expressed interest in this development.

Although there were commercial Omega receivers on the market most of these were designed for navigational purposes and were unsuitable for our need due to their cost and complexity. We were only aware of one commercial Omega receiver specifically designed for time keeping purposes. It had an output of only one pulse per minute and would have required substantial modifications to serve as a plug-in replacement for the VNG receiver.

Our objective in designing this unit was therefore to produce a simple, reliable unit that could be easily and cheaply produced and which would be adaptable to different applications. Circuit design was tailored around readily available off-the-shelf components to minimise production lead time.

In the front end design of this receiver, we benefitted from the work of a group in the Research School of Earth Sciences (RSES) of ANU under Dr Ken Muirhead (now with BMR) and Mr Anthony Percival.

The design of the Omega receiver was 'finalized' in September 1987 to enable production to commence. While we feel that a more elegant design could have evolved given more time, the present unit has been extensively tested, albeit only in Canberra, and should perform reliably in the field.

## 2. Omega Navigational Signal Format

The world-wide Omega navigational systems utilises a total of eight transmitters around the globe to provide a phase-sychronised Very Low Frequency (VLF) radio-navigation position fixing system. The VLF band of 10-14KHz has been allocated exclusively to the Omega transmissions.

Two types of frequencies are transmitted by each station: a unique frequency that identifies a specific station, and four common frequencies shared by all eight stations. The characteristic frequencies are mainly for time keeping and station identification whereas the common frequencies are for navigation. Each station transmits five frequencies at eight pre-designated time slots that repeat once every ten seconds.

As the Omega system is based on the principle of phase comparison between pairs of synchronous transmitters, precise time keeping and synchronisation are fundamental to the accuracy of the system. Each station is equipped with multiple, highly stable, caesium atomic frequency standards. They are regularly checked and adjusted in order to maintain the best possible accuracy of synchronisation. Therefore by locking into one pulse of the Omega signal frame, one can obtain timing reference traceable to the atomic clocks.

The Australian Omega station has a characteristic frequency of 13 KHz. The time slots of the characteristic frequency form two pairs of pulses as shown below:

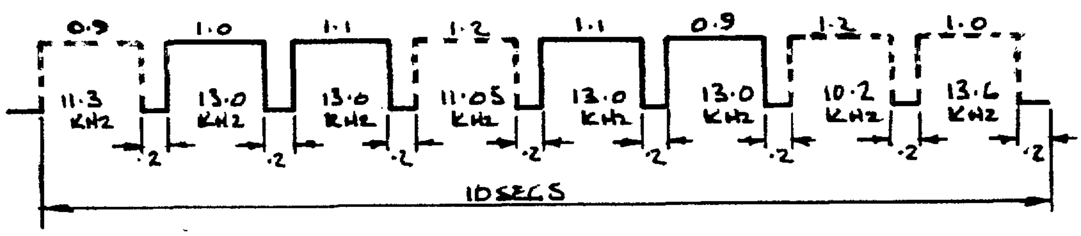



Figure 1

The longer pause between the fourth pulse and the first pulse of the following frame is used to distinguish the first pulse from the other three characteristic frequency pulses. The extraction of the first characteristic frequency pulse from the signal frame results in a one pulse per ten seconds timing reference signal which is used in turn to synchronise a 1 Hz timing signal derived from a local crystal oscillator.

The time mark generator gives an output of synchronised 1Hz signals with the longer duration 0.1Hz Omega signal pulse superimposed as a ten seconds marker.

## 3. Universal Co-ordinated Time

On 1 January 1972, when Omega operations began, Omega time was coincident with Universal Co-ordinated Time (UTC). The UTC is adjusted occasionally by 1s (a leap second) to account for the earth's rotation rate, but Omega time is not adjusted in this manner. Over the years, the Omega time has gradually departed from the UTC. In September 1987, Omega time was leading the UTC by 13s. In relative terms, the nearest Omega signal frame is leading UTC by 3s.

The first characteristic frequency pulse of the Australian signal frame begins 1.1s after the start of the frame sequence. Thus, this first characteristic pulse leads UTC by 1.9s.

In many applications, it is important to refer all timing information to UTC. Therefore the extracted Omega charateristic frequency pulse must be adjusted to make it coincide with UTC. In practice, a programmable digital delay line is introduced which can be adjusted year by year to derive UTC from Omega time.

## 4. Design Objective

The general design goal for this unit was to provide a time reference signal which could be used to correct for the accumulated drift of local clocks. The Omega system can only provide 10s markers relative to UTC, so local clocks must be accurate to within >5s between checks. The Omega Time-mark Generator, like the VNG receiver, does not provide an absolute time clock.

Specifically, the unit was designed to provide:

- Omega receiver that can decode the Australian characteristic frequency pulses to provide 10s time markers;
- a programmable digital delay time to adjust Omega time to UTC;
- a composite timing signal of 1s and 10s markers traceable to the Omega caesuim atomic clocks;
- plug-in compatibility to allow direct replacement of the Labtonics VNG receiver without modifying the existing equipment; and
- an active antenna to allow for the long cable required on some installations.

A detailed specification is given in Appendix 1.

## 5. Principle of operation

The period of time between corresponding pulses in consecutive pulse frames is 10 seconds. This property of the Omega signal is used to correct the drift of a 1Hz generator, consisting of a 1MHz crystal and dividers, by resetting it every 10 seconds. Thus, the error due to inaccuracy of the crystal cannot accumulate for more than 10 seconds.

To achieve pulses exactly 10 seconds apart, one pulse per frame must be isolated so that the time between corresponding pulses is exactly 10 seconds.

The carrier frequency of the pulses is 13kHz, the characteristic frequency of the Australian transmitter.

## 6. Summary of Operation

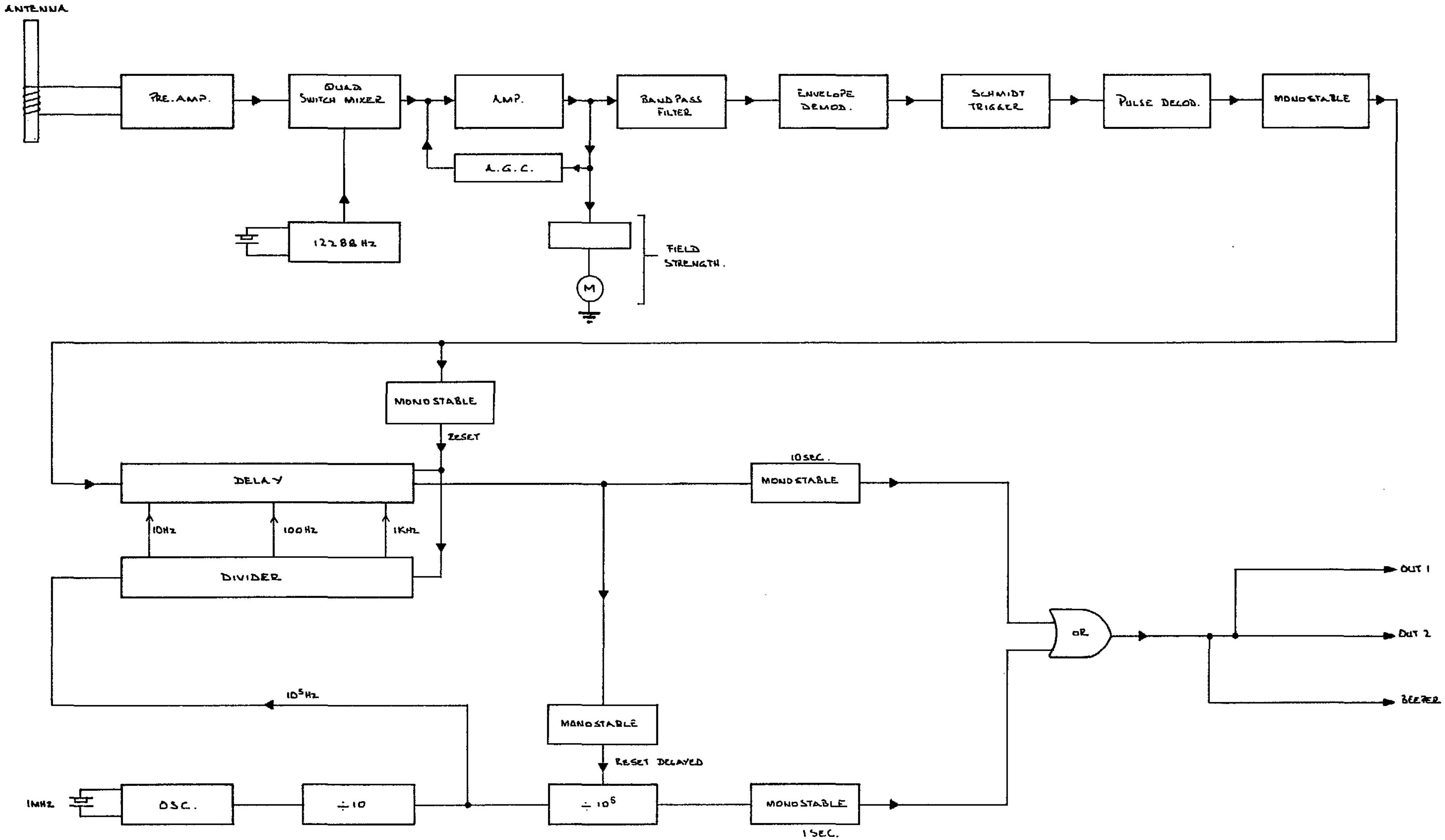
The 13kHz signal is tuned and amplified in a tubular aerial container. On the main board it is mixed with 12.288kHz to give an intermediate frequency (IF) of 712Hz.

The IF signal passes through a band pass filter where it is isolated from the other frequencies and amplified. The envelope of the 13kHz part of the Omega signal is detected and one pulse per frame isolated. This gives pulses 10 seconds apart. A delay line is also incorporated so that these pulses can be synchronized to Universal Co-ordinated Time.

The delayed Omega signal is used to reset the 1Hz generator so that every 10 seconds the 1Hz signal is corrected to the delayed Omega.

7. Block Diagram OMEGA TIME MARK GENERATOR






BLOCK DIAGRAM

FIG 2

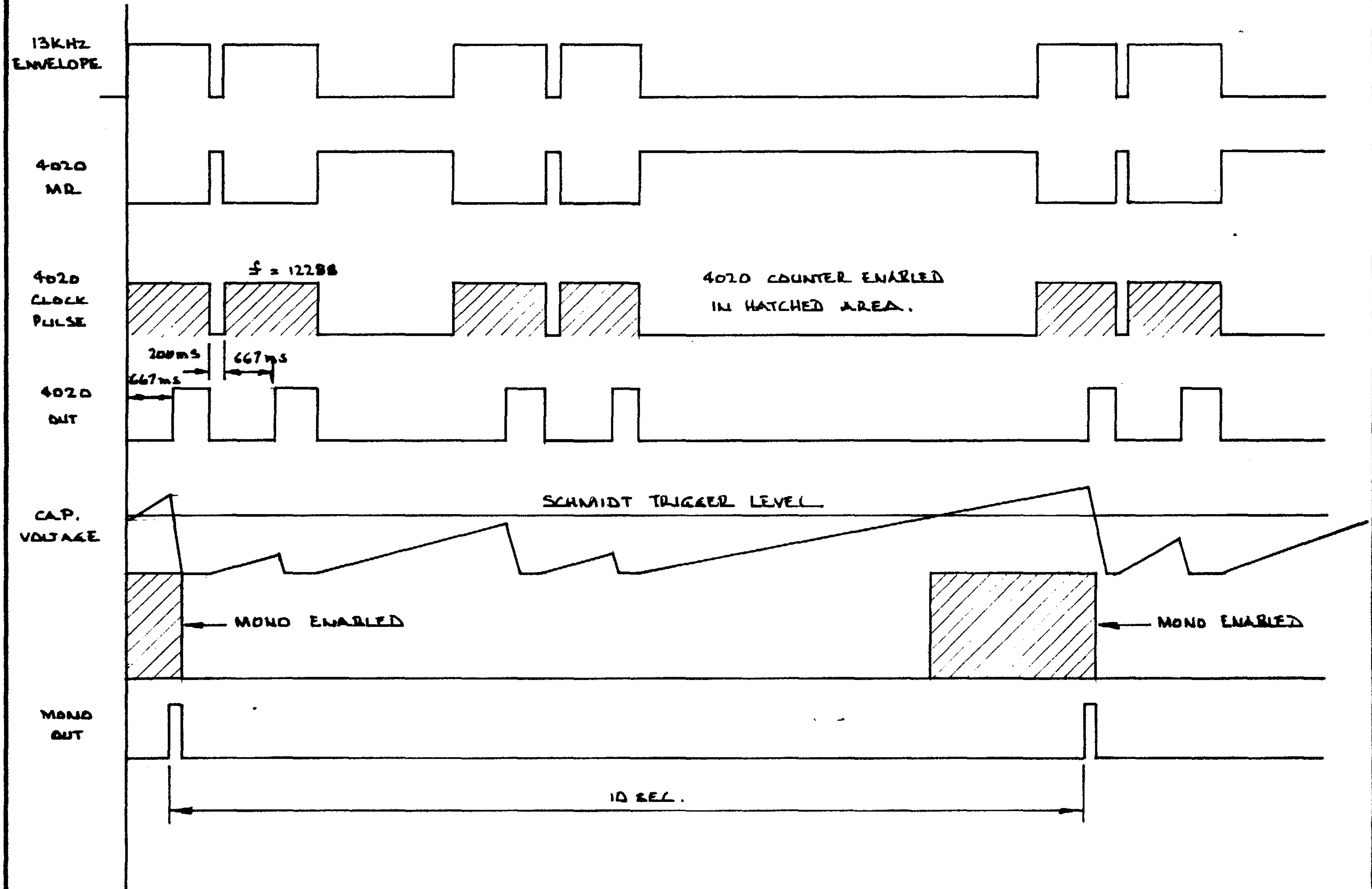



FIG 3 ENVELOPE DECODER TIMING

Title: OMEGA Rx. TIMING DIAGRAM

Issue 1

Date 3/11/87

Drawing No. N16

Sheet No. 4a

Drawn

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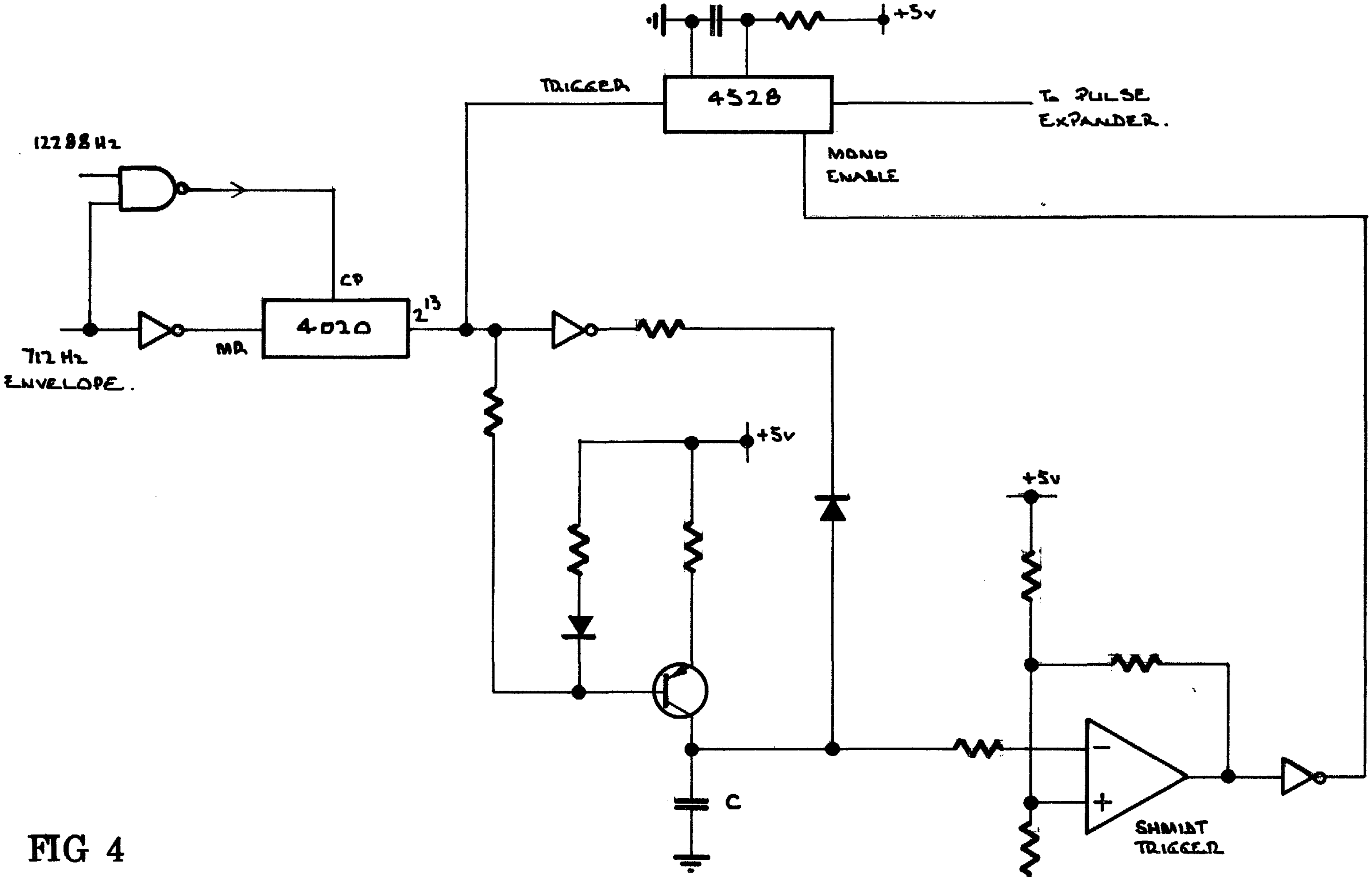


FIG 4

PULSE DECODER CIRCUITRY

Title:
Issue
Date
Drawing No.
Sheet No.
Drawn

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## 8. Details of Operation

Antenna and Pre-Amp The antenna consists of an inductor wound on a ferrite rod. This is part of a 13kHz parallel tuned circuit . A pre-amp is also included in the antenna housing.

Quad-Switch Mixer A square wave signal of 12.288kHz is generated by means of a 1,048.576kHz crystal oscillator and binary rate multipliers. 12.288kHz was chosen because it is clear of broadcast stations and 50Hz harmonics. This signal is mixed with the incoming 13kHz signal by means of a quad switch mixer made up of 4FET switches. One of the frequencies produced is the 712Hz intermediate frequency.

AGC The total signal from the mixer is amplified as indicated on the block diagram and the output level is used to provide automatic gain control.

Field Strength The level of the incoming signal is monitored by means of a meter thus enabling the optimum antenna orientation to be determined.

Band Pass Filter The output of the mixer includes a number of different frequencies. A parallel tuned circuit passes the 712Hz component and the others are excluded.

Envelope Demodulator The envelope of the 712Hz signal is detected by means of a capacitor and diode.

Schmidt Trigger This squares up the pulses produced by the envelope demodulator.

Pulse Decoder The function of the pulse decoder is to convert the envelope of the 712Hz IF signal into two pulses exactly 10 seconds apart. See Figures 3 & 4.

A 4020 counter is enabled while the envelope of the incoming signal is high. While it is enabled, it counts the pulses from the 12.288kHz signal. When it has counted $2^{13}$, the output goes high.

Period of clock pulse = 1/12288 = $8.138 \times 10^{-5}$ s

Therefore the time between enabling the counter and the output

$$= 2^{13} \times 8.138 \times 10^{-5} \text{ s}$$
$$= .6666 \text{ s}$$
$$= 667 \text{ ms}$$

The capacitor C is charged by a constant current source when the output of the 4020 is low. When it is high, it is discharged by the inverter I. By this means, the monostable is only enabled when the voltage rises above the Schmidt Trigger threshold. This enables the monostable to be triggered 667ms after two corresponding pulses in two consecutive 10s frames thus giving two pulses 10s apart.

<u>1 Hz Generator</u> A 1MHz crystal oscillator is divided by 10 to give $10^5$ Hz and then by $10^5$ to give 1Hz.

<u>Divider</u> The divider changes $10^5$ Hz to 10Hz, 100Hz and 1kHz. This gives the shift register delay line a 1ms increment interval.

<u>Delay</u> To bring the time code in line with UTC, the Omega signal which resets the 1Hz generator can be delayed by up to 7.104s in 1ms steps. Provision has been made to extend this to 9.999s if required.

<u>OR</u> The outputs from the 1s monostable and the delayed Omega monostable are "ORED" together for the output. The lengths of the pulses from the two monostables can be adjusted. It is usual to have the delayed Omega monostable set to a longer period so that an audible tone will indicate Omega is being received.

## 9. <u>Testing of Prototype</u>

When the Omega receiver was compared with a clock to determine the clock's drift, it was found that there was a scatter of $\pm$2ms between the two. On further investigation, it was found that this was due to the nature of the Omega signal. The users of the receiver decided that scatter of this magnitude did not matter as long as the error was not cumulative.

The Omega receiver was next tested to make sure that it could measure the drift in a clock. This was done by "tweaking" the crystal of a clock so that it drifted at about 1ms per 10 minutes. The clock was compared with the Omega signal after 15 hours operation. The error reading was 106ms which indicated that the Omega standard was capable of recording the drift in the clock. There was still the $\pm$2 ms scatter i.e. the actual readings were scattered between 104 and 108.

## 10. Testing Production Boards

After the power has been turned on, check that the 12.288kHz and the 1Hz signals are working.

Next tune and test the receiving section. This can be done by connecting a 13kHz oscillator to a coil of wire to act as a transmitter. With a CRO connected to the output of the pre-amp, slide the coil up and down the ferrite rod to get a peak.

Connect the CRO to the output of the Band Pass Filter and tune the inductor to give a peak in the 712Hz signal.

If correct, turn off the oscillator and orientate the antenna to receive the Omega signal at maximum strength. The Omega signal should be clearly seen on the output of the band pass filter.

Adjust the monostables for the 1s pulse and 10s Omega pulse to suit users' requirements.

## 11. Selection of Capacitors for the Tuned Circuits

We found that the best way to tune the two tuned circuits was by experiment. The inductors were tuned to the middle of their ranges by sliding the coil { of the way down the ferrite rod and screwing the slug { way down the ferrite core. A 13kHz signal was generated by connecting a 13kHz oscillator to a coil of wire.

A capacitance box was first placed in parallel with the antenna coil to form a tuned circuit. The capacitance box was then adjusted to give a peak at the output of the pre-amplifier. A fixed capacitor as near as possible in value to the capacitance box was chosen and soldered into the circuit. The circuit was then retuned by sliding the antenna coil up and down the ferrite rod.

The same process was carried out with the band pass filter except the signal was monitored at the output of the band pass filter and the inductor adjustment was made by screwing the slug in the ferrite core up and down.

The approximate values for the capacitors are 0.047uf for the 13kHz circuit and 1 f for the 712Hz circuit.

## 12. Setting the Digital Time Delay

See Appendix 2.

## 13. Additional Notes

The BMR Omega receiver is designed specifically for the Australian transmitter. Adaptation to other transmitters would involve not only modification of the radio frequency circuit but also of the pulse decoder.

The delay line is required so that the clock can be brought in line with UTC. This is so earthquake data can be compared with data from other organisations. The crustal study group do not require the delay line since their data is confined to the BMR.

Whether the delay line is set correctly or not can be determined by comparing the delayed Omega signal with a known UTC standard (e.g. Time pips from Telecom, time pips produced by the Navy)

## 14. Acknowledgements

Many people were involved in development and production of the Omega time mark generator.

Alan Scholtez spent many hours on preliminary circuit development.

Robbie Gan did the artwork for the printed circuit boards and drew the schematics.

Doug Cook did a great job in procuring all the parts for 70 boards as did the production team of Tom Stosic, Oscar Labasse and Phil Pope.

At the commencement of the project, the ANU provided us with circuits of developmental work they had done with Omega. These circuits were the starting point for development in the BMR and the ANU pre-amplifier was incoporated, without modification, in the BMR design.

## Appendix 1 Specification

| | |
|---|---|
| Antenna | Ferrite rod and coil externally housed in a plastic cylinder. |
| Pre-Amplifier | Housed in antenna cylinder Gain = 90dB |
| Frequency | Receiving frequency 13kHz<br>Intermediate frequency 712Hz |
| Power Requirements | 11mA at 12VDC |
| Accuracy | ±3ms |
| Output | 1Hz and 0.1Hz "ORED" together. Pulse lengths for both 1Hz and 0.1Hz adjustable. |
| Delay | With 1st shift register in circuit:<br>maximum 9.999s<br>minimum 0.211s<br>With 1st shift register out of circuit:<br>maximum 7.104s<br>minimum 0.111s |
| Mechanical | Antenna: Length 345mm<br>Diam 45mm<br><br>Unit: Width 150mm<br>Height 75mm<br>Length 310mm |

### Coil Winding Details

Antenna Coil: 2 layers, 100 turns per layer of 24SWG wire wound on a 204 x 9mm ferrite rod.

712 Band Pass filter: 8 layers of 28 SWG wire wound on RS 228-258 RM series ferrite core.

## Appendix 2 Presetting of Digital Delay Time.

The digital delay line comprises four stages of 64 bit shift register (4557B). The first two stages are driven by the 10Hz clock, whereas the 3rd stage is driven by 100Hz clock and last stage by 1kHz clock. Therefore the first two stages have an incremental delay of 100ms, and the last two stages have incremental delay of 10ms and 1ms respectively. Maximum delay for each stage is 63D where D is the incremental delay of that stage.

Each stage of the delay time is set by a 6 bit dual-in-line toggle switch in accordance with the table below.

| SW 6 | SW 5 | SW 4 | SW 3 | SW 2 | SW 1 | Total Delay |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 0D |
| 1 | 1 | 1 | 1 | 1 | 0 | 1D |
| 1 | 1 | 1 | 1 | 0 | 1 | 2D |
| 1 | 1 | 1 | 1 | 0 | 0 | 3D |
| 1 | 1 | 1 | 0 | 1 | 1 | 4D |
| | | and so on, to | | | | |
| 0 | 0 | 0 | 0 | 0 | 1 | 62D |
| 0 | 0 | 0 | 0 | 0 | 0 | 63D |

where 0 = switch off
1 = switch on
D = incremental delay.

The delay currently required to synchronise the 1st 13kHz pulse with UTC is 1.9s. The delay line is constructed such that if all the toggle switches are set to zero, there will be a delay of 0.211s. There is a delay of 0.667s between the first 13kHz pulse and the pulse which triggers the delay line.

Therefore delay setting required = 1.9 - .211 - .667s
= 1.022s

The settings to achieve this are:

| | SW 6 | SW 5 | SW 4 | SW 3 | SW 2 | SW 1 | Total Delay |
|---|---|---|---|---|---|---|---|
| 1st Stage (UX15) | 1 | 1 | 1 | 1 | 1 | 1 | 0.0s |
| 2nd Stage (U13) | 1 | 1 | 0 | 1 | 0 | 1 | 1.0s |
| 3rd Stage (U14) | 1 | 1 | 1 | 1 | 0 | 1 | 0.02s |
| 4th Stage (U15) | 1 | 1 | 1 | 1 | 0 | 1 | 0.002s |

Total 1.0 + 0.02 + 0.002

= 1.022s

Note

In a few early receivers, one of the first stage shift registers may not be fitted. Instead, the input & output points are linked. In this case 0.1s should be added to the delay settings.

UTC will be adjusted for a leap second in 1988. Therefore a delay of 2.9s will be required to synchronise the Omega receiver with UTC, i.e. 2.022s must be set on the delay line. The settings of the 1st, 3rd and 4th stages of the delay line remain the same. The second stage must be changed to 010111 for a delay of 2.0s. Any subsequent adjustment in UTC will involve setting the second stage to 3.0s, 4.0s, 5.0s, 6.0s, etc. Maximum delay for stage 2 is 6.3s. For a delay higher than 6.3s the first stage delay line should be introduced to take up part of the delay time required.

Example: To delay Omega pulse by 8.9s to make it coincidental with UTC. The delay required of the delay lines is 8.9 - 0.667 - 0.211 = 8.0225

| | |
|---|---|
| 1st stage: | 2s |
| 2nd stage: | 6.0s |
| 3rd stage: | 0.02s |
| 4th stage: | 0.002s |
| Total | 8.022s |