2.5 A generic echo sounding system

Compared with other systems, echo sounder circuitry is relatively simple. Most manufacturers of deep sounding systems now opt for microprocessor control and digital displays, but it was not always so. Many mariners preferred the paper-recording echo sounder because the display was clear, easy to read and provided a history of soundings.

Marconi Marine's 'Seahorse' echo sounder (Figure 2.11) was typical of the standard paper-recording echo sounder. Built in the period before microprocessor control, it is used here to describe the relatively simply circuitry needed to produce an accurate read-out of depth beneath the keel. From the description it is easy to see that an echo sounding system is simply a timing device.

The system used a transmission frequency of 24 kHz and two ranges, either manually or automatically selected, to allow depths down to 1000 m to be recorded. The shallow range was 100 m and operated with a short pulse length of 200 µs, whereas the 1000 m range uses a pulse length of 2 ms. Display accuracy for the chart recorder is typically 0.5% producing indications with an accuracy of ±0.5 m on the 100 m range and ±5 m on the deepest range.

2.5.1 Description

Receiver and chart recorder

When chart recording has been selected, transmission is initiated by a pulse from a proximity detector which triggers the chart pulse generator circuit introducing a slight delay, pre-set on each range, to ensure that transmission occurs at the instant the stylus marks zero on the recording paper. This system trigger pulse or that from the trigger pulse generator circuit when the chart is switched off, has three functions:

- to initiate the pulse timing circuit
- to operate the blanking pulse generator
- to synchronize the digital and processing circuits.

The transmit timing circuit sets the pulse length to trigger the 24 kHz oscillator (transmission frequency). Pulse length is increased, when the deep range is changed, by a range switch (not shown). Power contained in the transmitted signal is produced by the power amplifier stage, the output of which is coupled to the magnetostrictive transducer with the neon indicating transmission.

When the transmitter fires, the receiver input is blanked to prevent the high-energy pulse from causing damage to the input tuned circuits. The blanking pulse generator also initiates the swept gain circuit and inhibits the data pulse generator. During transmission, the swept gain control circuit holds the gain of the input tuned amplifier low. At cessation of transmission, the hold is removed permitting the receiver gain to gradually increase at a rate governed by an inverse fourth power law. This type of inverse gain control is necessary because echoes that are returned soon after transmission ceases are of large amplitude and are likely to overload the receiver.

The echo amplitude gradually decreases as the returned echo delay period increases. Thus the swept gain control circuit causes the average amplitude of the echoes displayed to be the same over the whole period between transmission pulses. However, high intensity echoes returned from large reflective objects will produce a rapid change in signal amplitude and will cause a larger signal to be coupled to the logarithmic amplifier causing a more substantial indication to be made on the paper. The logarithmic amplifier and detector stages produce a d.c. output, the amplitude of which is logarithmically proportional to the strength of the echo signal.

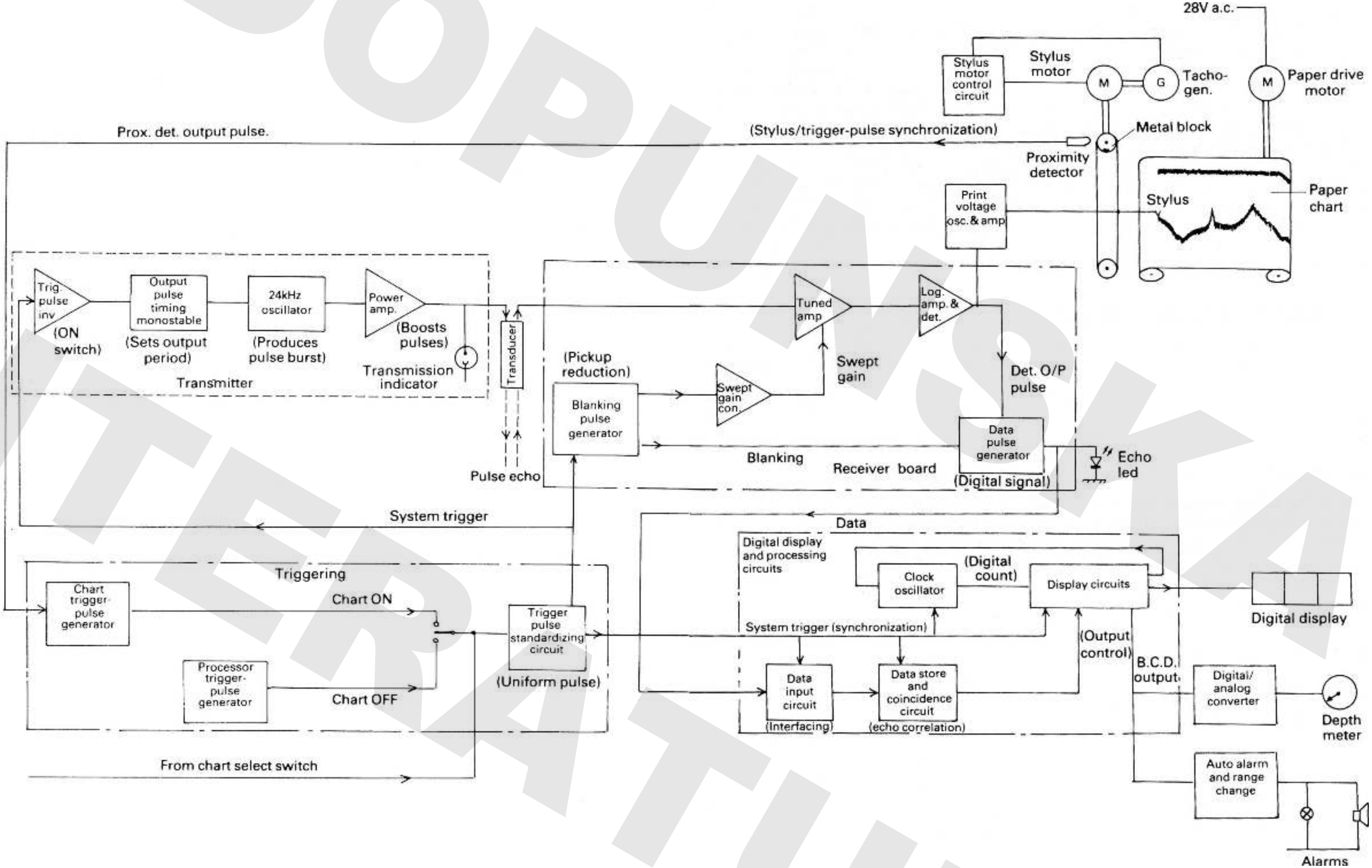

Figure 2.11 A block schematic diagram of the Seahorse echo sounder. (Reproduced courtesy of Marconi Marine.)

In the chart recorder display, electrosensitive paper is drawn horizontally beneath a sharp stylus. The paper is tightly drawn over the grounded roller guides by a constant speed paper-drive motor. Paper marking is achieved by applying a high voltage a.c. signal to the stylus which is drawn at 90° to the paper movement, across the surface of the paper on top of the left-hand roller. The paper is marked by burning the surface with a high voltage charge produced through the paper between the stylus and ground. Depending upon the size of the returned echo, the marking voltage is between 440 and 1100 V and is produced from a print voltage oscillator running at 2 kHz. Oscillator amplifier output is a constant amplitude signal, the threshold level of which is raised by the d.c. produced by a detected echo signal. Thus a high-intensity echo signal causes the marking voltage to be raised above the threshold level by a greater amount than would be caused by a detected small echo signal.

For accurate depth marking it is essential that the stylus tracking speed is absolutely precise. The stylus is moved along the paper by a belt controlled by the stylus d.c. motor. Speed accuracy is maintained by a complex feedback loop and tacho-generator circuit.

Digital circuits

The digital display section contains the necessary logic to drive the integral three-digit depth display, the alarm circuit, and the remote indicators. Pulse repetition frequency (PRF) of the clock oscillator is pre-set so that the time taken for the three-digit counter to count from 000 to 999 is exactly the same as that taken by the paper stylus to travel from zero to the maximum reading for the range in use. The counter output is therefore directly related to depth.

When the chart recorder is switched off, the digital processing section and the transmitter are triggered from the processor trigger pulse generator circuit. Both the transmit and receive sections work in the same way as previously described. A low logic pulse from the trigger pulse standardizing circuit synchronizes the logic functions. The d.c. output from the receiver detector is coupled via a data pulse generator circuit to the interface system. Unfortunately in any echo sounder it is likely that unwanted echoes will be received due to ship noise, aeration or other factors.

False echoes would be displayed as false depth indications on the chart and would be easily recognized. However, such echoes would produce instantaneous erroneous readings on the digital counter display that would not be so easily recognized. To prevent this happening echoes are stored in a data store on the processing board and only valid echoes will produce a reading on the display. Valid echoes are those that have indicated the same depth for two consecutive sounding cycles. The data store, therefore, consists of a two-stage counter which holds each echo for one sounding cycle and compares it with the next echo before the depth is displayed on the digital display.

The display circuit consists of three digital counters that are clocked from the clock oscillator circuit. Oscillator clock pulses are initiated by the system trigger at the instant of transmission. The first nine pulses are counted by the lowest order decade counter which registers 1–9 on the display least significant figure (LSF) element. The next clock pulse produces a 0 on the LSF display and clocks the second decade counter by one, producing a 1 in the centre of the display. This action continues, and if no echo is received, the full count of 999 is recorded when an output pulse from the counting circuit is fed back to stop the clock.

Each time transmission takes place the counters are reset to zero before being enabled. This is not evident on the display because the data output from the counters is taken via a latch that has to be enabled before data transfer can take place. Thus the counters are continually changing but the display data will only change when the latches have been enabled (when the depth changes). If an echo is received during the counting process, the output is stopped, and the output latches enabled by a pulse from the data store. The new depth is now displayed on the indicator and the counters are reset at the start of the next transmission pulse.

With any echo sounder, it is necessary that the clock pulse rate be directly related to depth. When the shallow (100 m) range is selected a high frequency is used which is reduced by a factor of 10 when the deep range (1000 m) is selected.

Modern echo sounders rely for their operation on the ubiquitous microprocessor and digital circuitry, but the system principles remain the same. It is the display of information that is the outward sign of the advance in technology.

2.6 A digitized echo sounding system

The Furuno Electric Co. Ltd, one of the world's big manufacturers of marine equipment, produces an echo sounder, the FE606, in which many of the functions have been digitized. Transmission frequency is either 50 or 200 kHz depending upon navigation requirements. A choice of 50 kHz provides greater depth indication and a wider beamwidth reducing the chance that the vessel may 'run away' from an echo (see Figure 2.10).

The pulse length increases with depth range from 0.4 ms, on the shallow ranges, to 2.0 ms on the maximum range. This enables better target discrimination on the lower ranges and ensures that sufficient pulse power is available on the higher ranges. Pulse repetition rate (sounding rate) is reduced as range increases to ensure adequate time between pulses for echoes to be returned from greater depths.

The system shown in Figure 2.12 is essentially a paper recorder and two LCD displays showing start depth and seabed depth. As before, transmission is initiated at the instant the stylus marks the zero line on the sensitive paper by a trigger sensor coupled to the control integrated circuits. Depending upon the range selected, the pulse length modulates the output from the transmit oscillator, which is power amplified and then coupled via a transmit/receive switch to the transducer.

A returned echo is processed in the receiver and applied to the logic circuitry. Here it is processed to determine that it is a valid echo and then it is latched through to a digital-to-analogue converter to produce the analogue voltage to drive the print oscillator. Thus the depth is marked on the sensitive paper at some point determined by the time delay between transmission and reception, and the distance the stylus has travelled over the paper.

2.7 A microcomputer echo sounding system

As you would expect, the use of computing technology has eliminated much of the basic circuitry and in most cases the mechanical paper display system of modern echo sounders. Current systems are much more versatile than their predecessors. The use of a computer enables precise control and processing of the echo sounding signal. Circuitry has now reached the point where it is virtually all contained on a few chips. However, the most obvious changes that users will be aware of in modern systems are the display and user interface.

Once again there are many manufacturers and suppliers of echo sounders or, as they are often now called, fish finders. The Furuno navigational echo sounder FE-700 is typical of many. Depending upon requirements the system is able to operate with a 200 kHz transmission frequency giving high-resolution shallow depth performance, or 50 kHz for deep-water sounding.

Seabed and echo data is displayed on a 6.5 inch high-brightness TFT colour LCD display which provides the navigator with a history of soundings over a period of 15 min, much as the older paper recording systems did (see Figure 2.13).

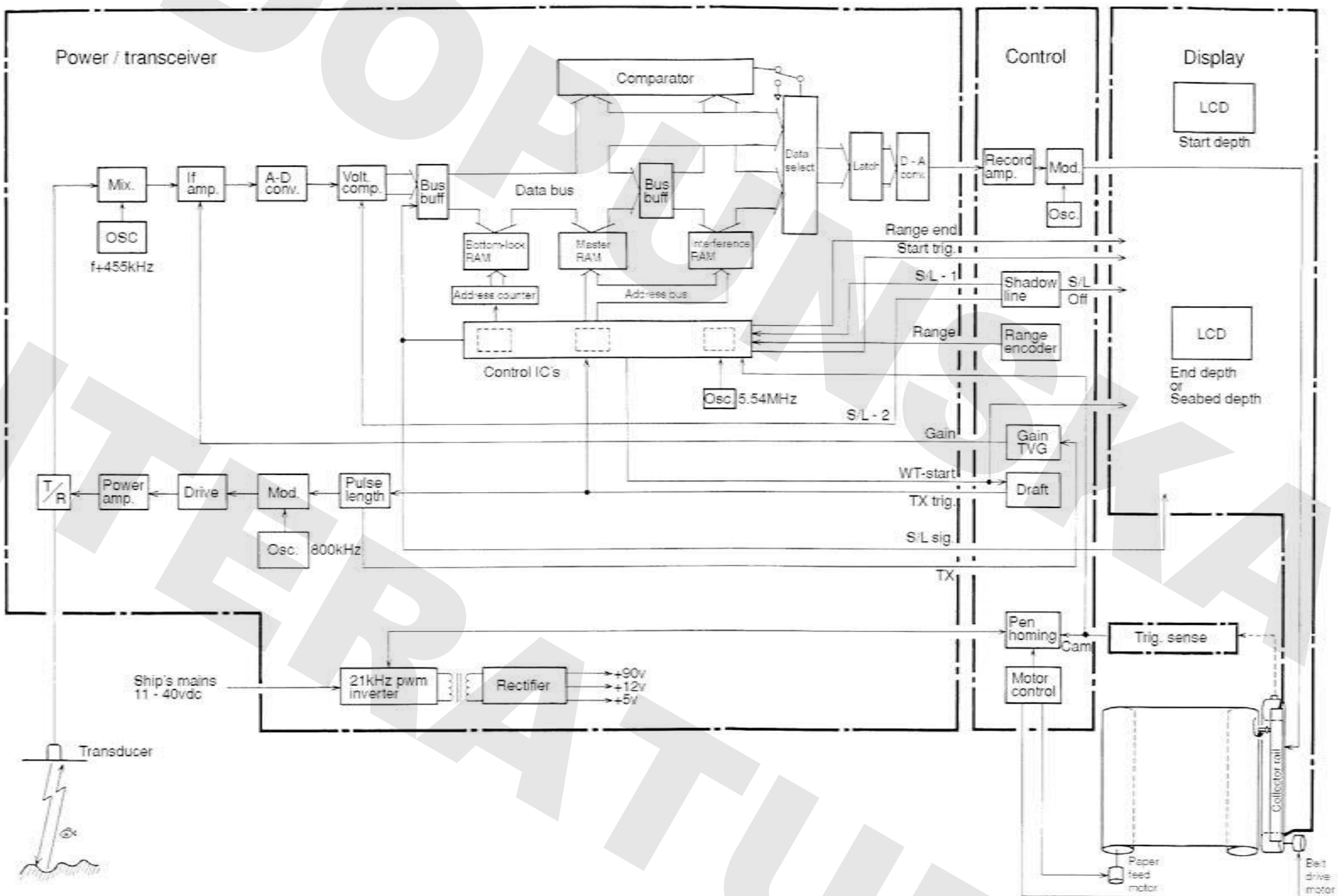

Figure 2.12 Furuno FE-606 echo sounding system. (Reproduced courtesy of Furuno Electric Co.)

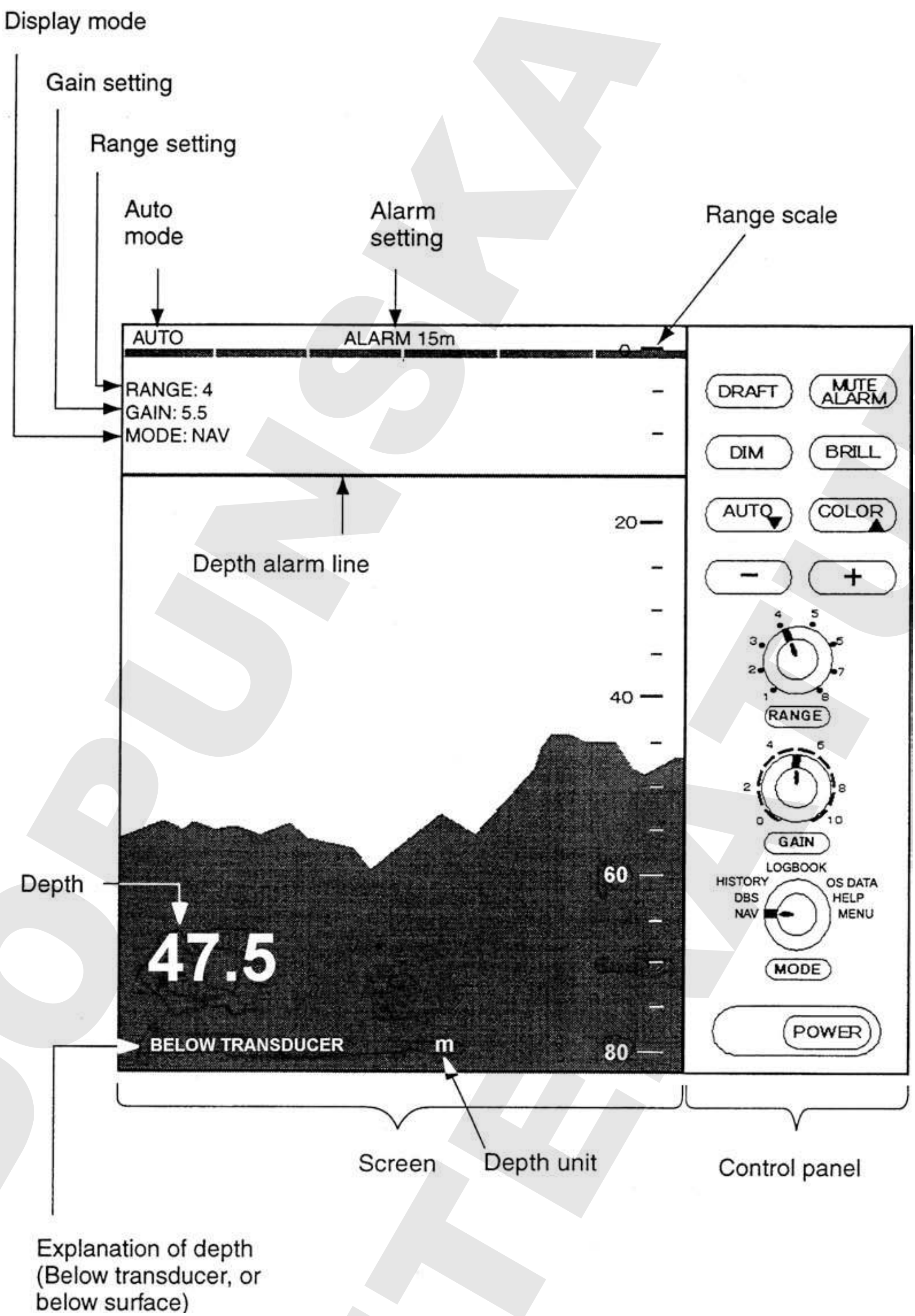

Figure 2.13 Furuno FE-700 LCD TFT data display (Navigation Mode.) (Reproduced courtesy of Furuno Electric Co.)

Depths, associated time, and position are all stored in 24-h memory and can be played back at any time. This is a useful function if there is any dispute following an accident.

The main depth display emulates a cross-sectional profile of the ocean over the past 15 min. At the top of the display in Figure 2.13, the solid zero line marks the ocean surface or transducer level whichever is selected. At 15 m down, a second line marks the depth at which the alarm has been set. The undulating line showing the ocean floor depth is shown varying over 15 min from 58 to 44 m and the instantaneous depth, also shown as a large numerical display, is 47.5 m. Other operation detail is as shown in the diagram. What is not indicated on the display is the change of pulse length and period as selected by range.

As shown in Table 2.2, the pulse length is increased with the depth range to effectively allow more power to be contained in the transmitted pulse, whilst the pulse period frequency is reduced to permit longer gaps in the transmission period allowing greater depths to be indicated

Table 2.2 Echo sounder range vs pulse length vs PRF

Depth (metres)	*Pulse length (ms)*	*PRF (pulses per minute)*
5, 10 and 20	0.25	750
40	0.38	375
100	1.00	150
200	2.00	75
400 and 800	3.60	42

In addition to the standard navigation mode, Furuno FE-700 users are provided with a number of options adequately demonstrating the capability of a modern echo sounder using a TFT LCD display (see Figure 2.14). All the selected modes display data as a window insert on top of the echo sounder NAV mode display.

There are four display-mode areas.

- OS DATA mode. Indicates own ship position, GPS derived course, time and a digital display of water depth.
- DBS mode. Provides a draft-adjusted depth mode for referencing with maritime charts.
- LOGBOOK mode. As the name suggests, provides a facility for manually logging depths over a given period.
- HISTORY mode. Provides a mixture of contour and strata displays. The contour display can be shifted back over the past 24 h whilst the strata display (right-hand side of display) shows sounding data over the last 5 min.

2.8 Glossary

The following lists abbreviations, acronyms and definitions of specific terms used in this chapter.

Aeration Aerated water bubbles clinging to the transducer face cause errors in the system.

Ambient noise Noise that remains constant as range increases.

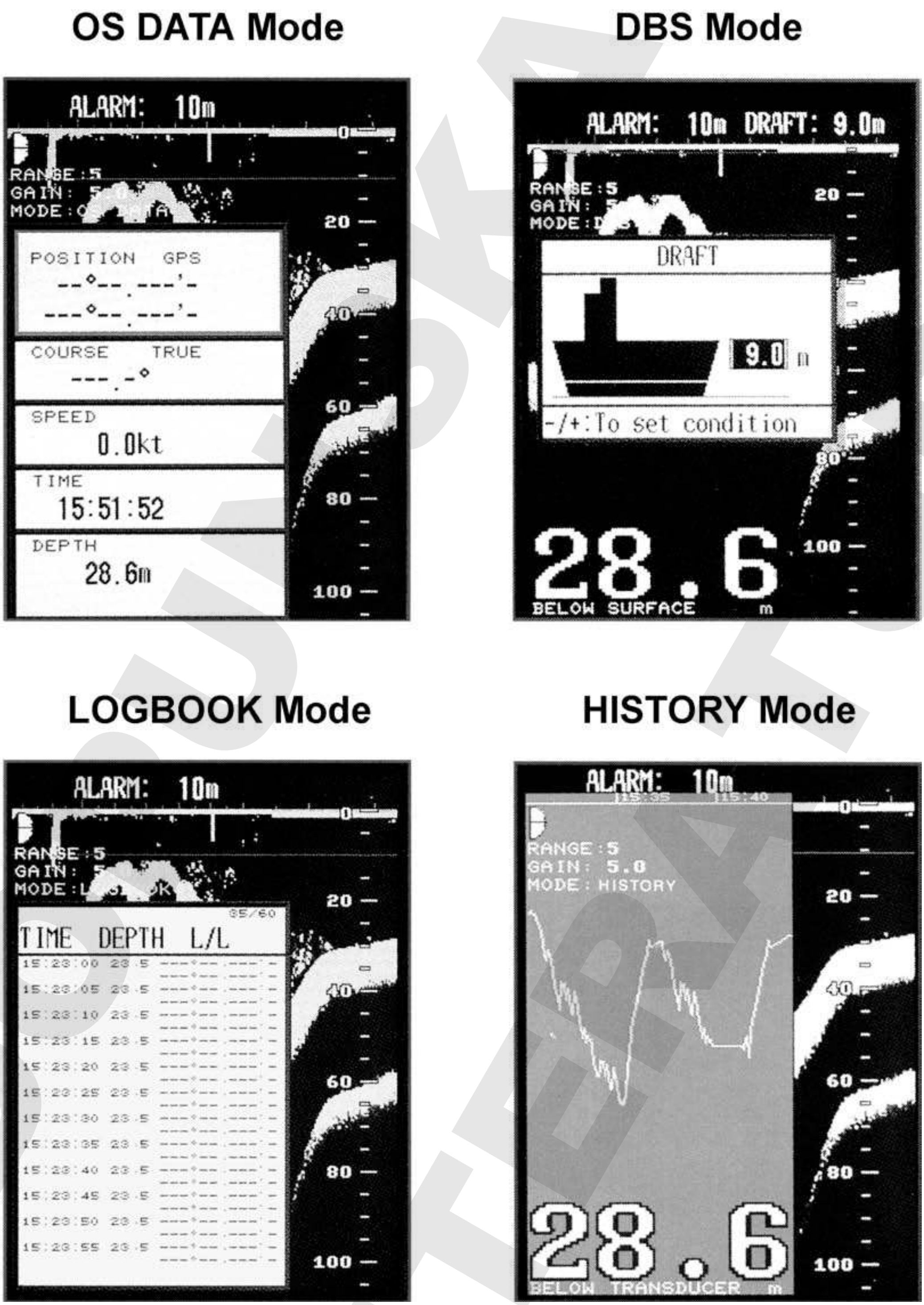

Figure 2.14 Different display modes demonstrating the flexibility of a microcomputer-controlled echo sounder. (Reproduced courtesy of Furuno Electric Co.)

Beam spreading The transmitted pulse of energy spreads as it travels away from the transducer. The use of a wide beam will cause noise problems in the receiver and a narrow beam may lead to an echo being missed as the vessel steams away from the area.

Chart recorder A sensitive paper recording system which, when the surface is scratched by a stylus, marks the contour of the ocean floor.

Continuous wave system An echo sounding system that uses two transducers and transmits and receives energy at the same time.

Electrostrictive transducer A transducer design based on piezoelectric technology. It is used when a higher transmission frequency is needed such as in speed logging equipment or fish-finding sounders.

Magnetostrictive transducer A design based on magnetic induction. A large heavy transducer capable of transmitting high power. Used in deep sounding systems.

Pulse duration (length) The period of the transmitted pulse when the transmitter is active.

Pulse repetition frequency (PRF) The number of pulses transmitted per minute by the system. Similar to RADAR

Pulse wave system A system that, like RADAR, transmits pulses of energy from a transducer which is then switched off. The received energy returns to the same transducer.

Reverberation noise Noise that decreases as range increases.

Sonar *So*und *n*avigation *a*nd *r*anging.

Velocity Speed of acoustic waves in seawater; 1505 ms^{-1} or approximated to1500 ms^{-1}.

2.9 Summary

- Sonar stands for *so*und *n*avigation *a*nd *r*anging.
- Sound travels relatively slowly in seawater at 1505 ms^{-1}. This is approximated to 1500 ms^{-1} for convenience.
- The velocity is not a constant, it varies with the salinity of seawater. Ocean salinity is approximately 3.4%.
- Transmitted signal amplitude is attenuated by saltwater and the ocean floor from which it is reflected.
- Noise caused by sea creatures and ocean activity is a major problem affecting sonar equipment.
- The temperature of the seawater affects the velocity of the acoustic wave and consequently affects the accuracy of the displayed data. Temperature sensors are contained in the transducer housing to produce corrective data.
- Transducers are effectively the antennas of sonar systems. They transmit and receive the acoustic energy.
- There are two main types of transducer in use; magnetostrictive and electrostrictive. Magnetostrictive transducers are large and heavy and tend to be used only on large vessels. Electrostrictive transducers are lighter and often used in speed logging systems and on smaller craft.
- Low frequencies are often used in deep sounding systems typically in the range 10–100 kHz.
- The depth below the keel is related to the time taken for the acoustic wave to travel to the ocean floor and return. Put simply if the delay is 1 s and the wave travels at 1500 ms^{-1} then the depth is $0.5 \times 1500 = 750$ m.

- Pulsed systems, like those used in maritime RADAR, are used in an echo sounder. The pulse length or duration determines the resolution of the equipment. A short pulse length will identify objects close together in the water. If all other parameters remain constant, the pulse repetition frequency (PRF), the number of pulses per minute, determines the maximum range that can be indicated.
- The width of the transmitted beam becomes wider as it travels away from the transducer. It should not be excessively narrow or the vessel may 'run away' from, or miss, the returned echo.
- Modern echo sounding equipment is computer controlled and therefore is able to produce a host of other data besides a depth indication.

2.10 Revision questions

1 Why do deep sounding echo sounders operate with a low transmission frequency?
2 For a given ocean depth, how is it possible for returned echoes to vary in strength?
3 If a vessel sails from salt water into fresh water the depth indicated by an echo sounder will be in error. Why is this and what is the magnitude of the error?
4 Noise can degrade an echo sounder display. How does narrowing the transmitted beamwidth reduce system noise and at what cost?
5 Why are electrostrictive transducers used in maritime applications in preference to piezoelectric resonators?
6 Why do marine echo sounding systems use pulsed transmission and not a continuous wave mode of operation?
7 Many echo sounders offer the ability to vary the transmission pulse duration. Why is this?
8 How are the pulse repetition frequency (PRF) and the maximum depth, indicated by an echo sounding system, related?
9 Why is the siting of an echo sounder transducer important?
10 What do you understand by the term target discrimination?
11 What effect may a narrow transmission beamwidth have on returned echoes if a ship is rolling in heavy seas?