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TIME-AMPLITUDE-FREQUENCY (T-A-F)

A special electronic unit for measuring
the TVG function of research echo sounders

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ABSTRACT

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High precision in hydroacoustic instruments for fisheries research demands high precision and reliability in the test instruments. To simplify the test measurements, a special test unit has been developed. The operating principles are described, and a technical description is given for this special-purpose signal generator. Application of the unit is described in detail, and an easy way to verify the accuracy of signal amplitude and frequency is recommended. Finally a computational example to derive correction factors is given.

INTRODUCTION

As the calibration of echo sounders by standard spheres (FOOTE, KNUDSEN and VESTNES, 1983) has become routine, it has become necessary to measure the time-varied gain (TVG) in the echo sounders's receiver with greater accuracy. The particular method of calibration by optimal copper spheres has so increased the potential accuracy of general hydroacoustic measurements that knowledge of the TVG function has become a limiting factor. Given its detailed description, however, corrections can be applied to the function to maintain its accuracy.

Until recently, the TVG measurement has been accomplished by a battery of standard instruments which have included a signal generator, frequency counter, voltmeter, oscilloscope, etc. This indicates in itself that interconnection of the instruments is both time-consuming and susceptible to errors in instrument settings, not to mention in their essential reading.

The value of a special electronic unit which can measure the TVG function without requiring a large number of separate instruments is thus evident. The resultant simplification may also be expected to be accompanied by an increase in reliability.

OPERATING PRINCIPLE

The unit contains all of the necessary functions for generating a precise test signal. The signal may consist of either a continuous sinusoid or pulses. This is crystal-stabilized at the nominal frequency of the echo sounder. In order to avoid saturation in the receiver and at the same time to be able to read a reasonably large amplitude in the first part of the TVG sequence, the signal is high for the first 100 m before being attenuated by 20 dB for the duration of the sequence.

Fig. 1a shows the sinusoidal test signal. Fig. 1b shows the corresponding output signal from the receiver. The particular receiver used here is that of the SIMRAD EK400 echo sounder, with nominal frequency of 38 kHz.

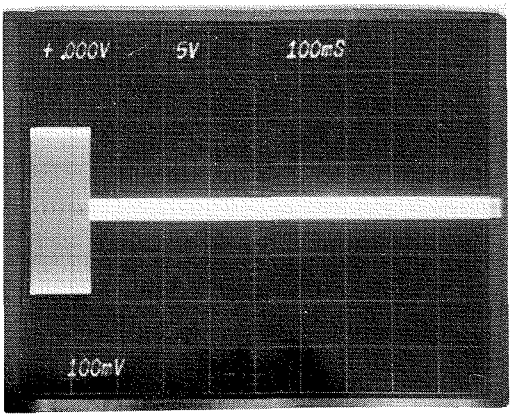

Fig. 1a. Applied signal, a continuous sinusoid. Scales: 5 V/cm on vertical, 100 ms/cm on horizontal.

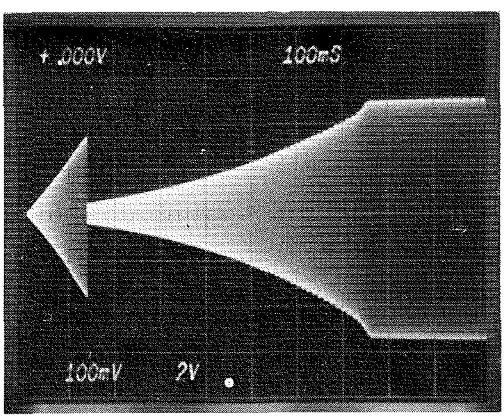

Fig. 1b. Calibrated output signal. TVG «20 log R». Attenuator −20 dB. Scales: 2 V/cm on vertical, 100 ms/cm on horizontal.

By means of an oscilloscope with a time-delay function, the output signal can be read at any depth and the measured value compared with the corresponding theoretically calculated value. The two values and their difference in decibels can be entered in a table. Both the instrument reading and computation can be performed quickly and accurately by means of a computer coupled to the echo sounder's output.

PULSE OPERATION

The unit can also genrate test signals in the form of pulses. These pulses have identical durations of 1 ms, and are sent at fixed intervals after the trigger pulse. The time intervals are based on a sound speed of 1500 m/s and a definite range of depths. A total of 20 pulses are transmitted in a train, with time delays regulated by the trigger pulse, corresponding to the following depths: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250,.300, 350, 400, 450, 500, 550, and 600 m.

Fig. 2a shows the test signal in the form of pulses and Fig. 2b the resulting calibrated output signal of the echo sounder. By means of an oscilloscope, the amplitude due to each individual pulse can be measured and compared with the theoretical value. Precise measurements of time are unnecessary since the pulses correspond to definite depths as regulated by crystal-stabilized circuitry.

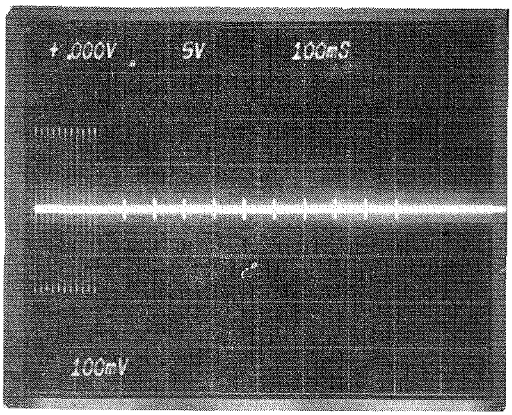

Fig. 2a. Applied signal. Repeated tone burst. Pulse duration 1 ms. Scales: 5 V/cm on vertical, 100 ms/cm on horizontal.

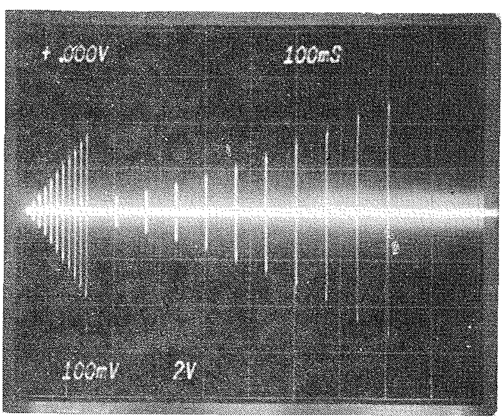

Fig. 2b. Calibrated output signal. TVG «20 log R». Attenuator −20 dB. Scales: 2 V/cm on vertical, 100 ms/cm on horizontal.

In addition to the fixed pulses, there is another pulsed signal type allowing arbitrary positioning, hence stepwise adjustment of the pulse over the entire TVG range.

It is important to note that the amplitude due to a pulsed signal is somewhat greater than that due to a continuous sine wave because of the receiver's pulse response and bandwidth. Figs. 3a and b show superimposed the continuous signal and pulse number 19 at the respective test input and calibrated output parts of the receiver. The bandwidth is 3.3 kHz. It is noted that the calibrated output signal amplitude is 0.8 dB higher with the pulse than with the continuous signal. Table 1 shows the computed and measured responses of an EK400/38 echo sounder.

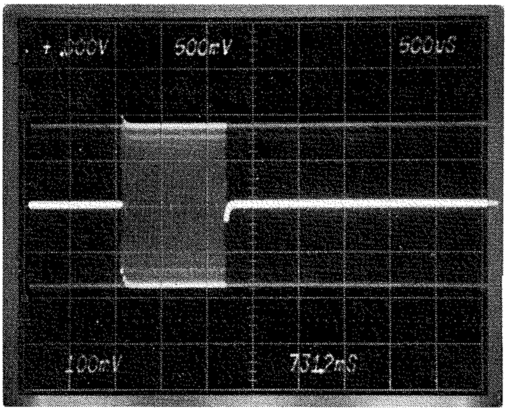

Fig. 3a. Superposition of applied CW signal and pulse no. 19. Time delay: 731.2 ms. Scales: 500 mV/cm on vertical, 500 μs/cm on horizontal.

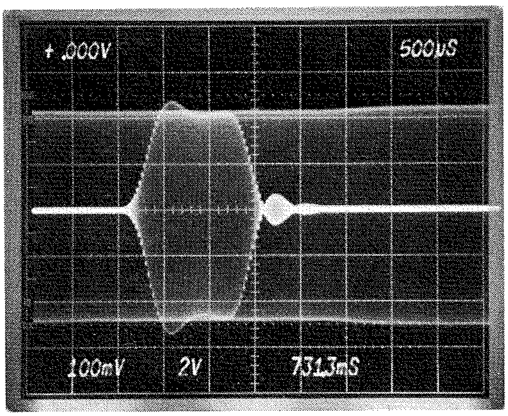

Fig. 3b. Superposition of calibrated output signal and pulse no. 19. Time delay: 731.3 ms. Scales: 2 V/cm on vertical, 500 μs/cm on horizontal.

The upper nine readings have been made with the variable pulse which can be manually positioned.

Table 1. Manually measured values compared to nominal values for an EK 400/38 kHz echo sounder.

Depth (metres)	Measured values (volts peak)	Nominal values (volts peak)	Deviation (dB)	Correction factor
1.425	.082	.037	6.91	.204
2	.085	.052	4.24	.374
3	.080	.079	.11	.975
4	.101	.104	–.25	1.060
5	.127	.131	.27	1.064
6	.162	.158	.22	.951
7	.191	.184	.32	.928
8	.218	.211	.28	.937
9	.243	.238	.18	.959
10	.277	.265	.38	.915
20	.559	.540	.31	.933
30	.827	.825	.02	.995
40	1.11	1.12	–.08	1.02
50	1.41	1.43	.12	1.03
60	1.73	1.74	–.05	1.01
70	1.98	2.07	–.39	1.09
80	2.30	2.41	–.41	1.10
90	2.65	2.76	–.35	1.08
100	3.01	3.13	–.34	1.08
150	.502	.515	–.22	1.05
200	.729	.752	–.27	1.06
250	1.01	1.03	–.17	1.04
300	1.33	1.36	–.19	1.05
350	1.72	1.74	–.10	1.02
400	2.14	2.18	–.16	1.04
450	2.65	2.68	–.10	1.02
500	3.19	3.27	–.22	1.05
550	3.93	3.94	–.02	1.01
600(582)	4.41	4.41	0	1.00

INTEGRATION

A more accurate and more realistic method for measuring the TVG function is based on integration of each individual pulse. If the reference point is taken at the last pulse, number 20, which lies at the expiration of the TVG, the relative values of the precedings pulses can be computed and thus compared with the integrator's output.

The amplitude at each depth u_r is computed from the amplitude u_{max} at TVG expiration in the following manner:

$$u_r = u_{max} - (20 \log R + 2\alpha R) + 20 \log r + 2\alpha r \qquad (1)$$

where R is the total TVG range, r is the acutal measurement depth, and α is the absorption coefficient used in the receiver.

The integral of the square of the test pulse is proportional to the square of the amplitude. If the integral of the pulse at expiration of the TVG function is known, viz.

$$M_{max} = k \int_{t_1}^{t_2} u^2 dt$$

then the integral of the pulse at the arbitrary depth r is

$$M_r = \frac{U_r^2}{U_{max}^2} \cdot M_{max}$$

Table 2 contains the computed values of voltage together with the factor u^2_r/u^2_{max} for computing the integrals. The factor is computed for the EK 400/38 with the TVG function at expiration, 20 log R + 2αR, where R = 581 m and α = 0.008 dB/m.

Table 2. Computed values for the EK400/38 kHz echo sounder 20 log R + 2αR = 64.58.

Pulse no.	Depth (m)	u_r (dB)	u_r (V_{p-p})	$\frac{u_r^2}{u_{max}^2}$
1	10	−13.45	0.60	0.0036
2	20	− 7.27	1.23	0.0150
3	30	− 3.59	1.88	0.0350
4	40	− 0.93	2.55	0.0646
5	50	1.17	3.25	0.1047
6	60	2.91	3.97	0.1564
7	70	4.41	4.72	0.2209
8	80	5.73	5.49	0.2994
9	90	6.91	6.29	0.3931
10	100	7.99	7.12	0.5036
11*	150	− 7.69	1.17	0.0136
12	200	− 4.39	1.70	0.0291
13	250	− 1.65	− 2.34	0.0547
14	300	0.73	3.10	0.0947
15	350	2.87	3.94	0.1549
16	400	4.83	4.97	0.2433
17	450	6.65	6.18	0.3702
18	500	8.37	7.44	0.5495
19	550	10.00	8.94	0.7994
20	600	11.00	10.00	1.0000

*) From 100 m and the rest of the TVG range the test signal is attenuated 20.0 dB.

Table 3 shows the corresponding numbers for the EK38, for which R = 500 m and α = 0.0105 dB/m.

Table 3. Computed values for the EK38 or EK-S-38 echo sounders. 20 log R + 2αR = 64.48.

Pulse no.	Depth (m)	u_r (dB)	u_r (V_{p-p})	$\frac{u_r^2}{u_{max}^2}$
1	10	−13.27	0.61	0.0038
2	20	− 7.04	1.25	0.0158
3	30	− 3.31	1.93	0.0374
4	40	− 0.60	2.64	0.0697
5	50	1.55	3.38	0.1143
6	60	3.34	4.16	0.1728
7	70	4.89	4.97	0.2468
8	80	6.26	5.82	0.3383
9	90	7.50	6.70	0.4494
10	100	8.62	7.63	0.5823
11*	150	− 6.81	1.29	0.0167
12	200	− 3.26	1.94	0.0378
13	250	− 0.27	− 2.74	0.0752
14	300	2.36	3.71	0.1378
15	350	4.75	4.89	0.2389
16	400	6.96	6.30	0.3974
17	450	9.03	8.00	0.6406
18	500	11.00	10.00	1.0000
19	550	11.00	10.00	1.0000
20	600	11.00	10.00	1.0000

*) From 100 m and the rest of the TVG range the test signal is attenuated 20.0 dB.

TECHNICAL DESCRIPTION

The unit consists of two major components: a timing unit and a signal generator. These are shown in a simplified block diagram in Fig. 4.

TIMING UNIT

The timing unit controls the pulse gate and the attenuator of the signal generator. The timing sequence is activated by the echo sounder's trigger pulse.

Input ports are provided for both positive and negative trigger pulses in order to accept trigger pulses of either polarity. A warning light blinks whenever the wrong port is used.

When the trigger pulse arrives, the signal TRIGG is generated. This signal starts a bistable multivibrator which in turn opens the gate which controls the 75 kHz signal from the oscillator – frequency divider. The frequency is divided first by 1000, producing a frequency which corresponds to one pulse per 10 m path length in water. This 10 m pulse is steered through a gate where it is again

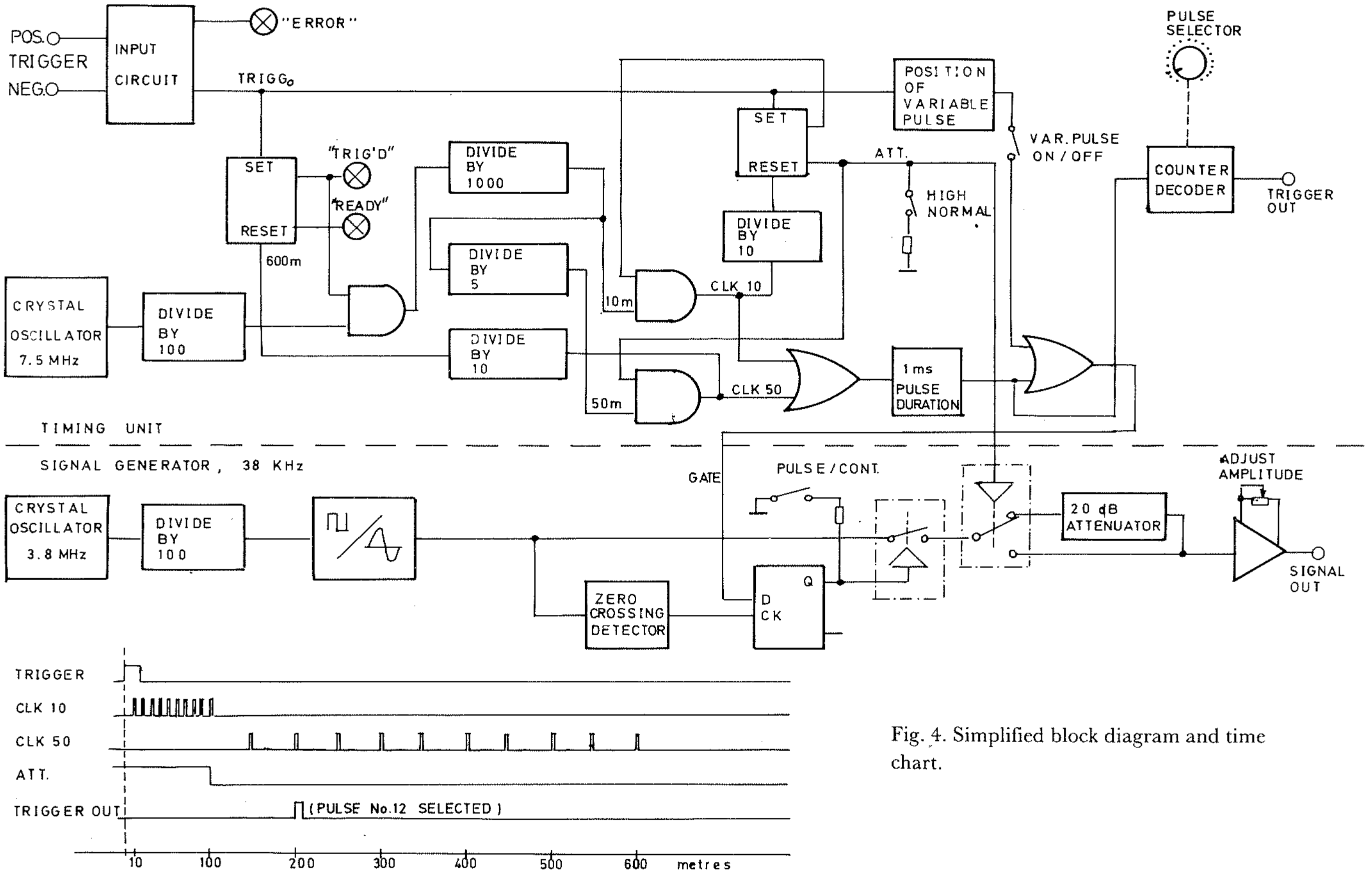

Fig. 4. Simplified block diagram and time chart.

divided, this time by 10. After a time corresponding to 100 m in water, the multivibrator is reset and the gate for the 10 m pulses is closed. This multivibrator also controls the signal generator's attenuator.

At the same time the multivibrator is reset, another gate is opened, generating a 50 m pulse. In this way, 10 pulses with 10 m intervals are first conducted to the signal generator's gate, followed by pulses with 50 m intervals. The signal CLK50 is returned via a divider to the first multivibrator, stopping the 75 kHz signal when 600 m is reached.

SIGNAL GENERATOR

The crystal oscillator has a frequency which is several decades higher than that of the echo sounder. It is divided downwards to the nominal echo sounder frequency, and then transformed in a special converter to a sinus signal. A zero-crossing detector and a D flip-flop ensure that the gate pulse opens the signal generator's pulse gate when the signal voltage exceeds null. A pure pulse is thus derived.

In the first 100 m the signal goes directly to the output amplifier. The attenuator is then coupled in. The pulse gate and the attenuator switch are constructed with MOSFET circuits. The output amplifier is a stabilized amplifier with low impedance output.

PULSE SELECTOR

In order to simplify reading of the oscilloscope, a separate trigger port is provided. This is controlled by a pulse-selection switch. Steps numbered from 0 to 20 are provided. In position 0 the triggering occurs simultaneously with the echo sounder's triggering. In the other positions, trigger pulses corresponding to the respective pulses are provided. The TRIGGER OUTPUT pulse is positive, 12 V in amplitude and 4 ms in duration.

USER NOTES

The T-A-F unit, as mentioned earlier, contains all the necessary components for generating a test signal. The interconnections of the test instrumentation are shown in Fig. 5. The echo sounder's trigger pulse is connected to the appropriate trigger input channel. An error in the choice of the polarity is indicated by blinking of the error light.

The echo sounder is adjusted to 250 m basic operating range, then the trigger pulse arrives, the READY signal disappears, and the TRIG'D indicator lights up. This last-mentioned indicator remains on for 800 ms which is slightly longer than the operating time of «20 log r» TVG in the EK38.

If the echo sounder is run at too high a pulse-repetition frequency (PRF), then the READY indicator will never light up and the trigger will occur asynchronously, causing erroneous readings.

MEASUREMENT OF PULSES

1. Set the PULSE/CW switch in the PULSE position.
2. Set the HIGH/NORMAL switch in the NORMAL position.

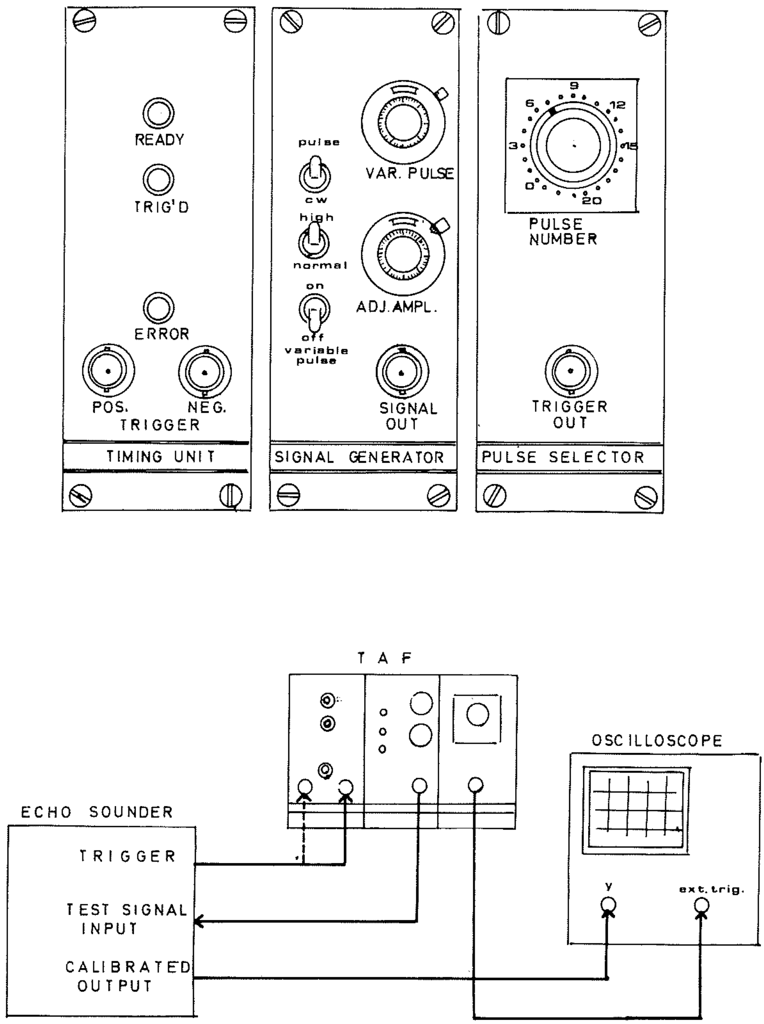

Fig. 5. Control panel of the T-A-F unit and the interconnections of the test instrumentation.

3. Couple the OUTPUT SIGNAL to the echo sounder's TEST input. Note that in the EK 400 the coupling occurs through a transducer input with 50 dB attenuator.
4. Connect TRIGGER OUT to Ext. trigger on the oscilloscope.
5. Read the echo sounder's CALIBRATED OUTPUT SIGNAL on the oscilloscope. Adjust the signal amplitude by means of the potentiometer AMPLITUDE ADJUSTMENT to 10.0 V_{p-p} at the TVG expiration. This is done with pulse number 20, the last pulse, which follows the trigger pulse by 800 ms.
6. Read the amplitudes of the remaining 19 fixed pulses on the oscilloscope and record in a table where they may be compared with the theoretical values.

Figs 6 and 7 show examples of two pulses, numbers 1 and 10, respectively. Tables 2 and 3 show the theoretical values for the EK 400/38 and EK 38, respectively.

If the TVG is to be measured at ranges intermediate to those of the fixed pulses, the variable pulse can be used. The switch VARIABLE PULSE is turned on, and the potentiometer VARIABLE PULSE is adjusted until the pulse is in the desired position. The theoretical value is computed through Eq. (1). A computational example is presented below.

VERIFICATION OF THE T-A-F UNIT

In order to verify the operation of the T-A-F unit, the following instruments are needed: (1) frequency counter, and (2) electronic voltmeter.

The switch PULSE/CW is set in the position CW.

The switch HIGH/NORMAL is set in the position NORMAL.

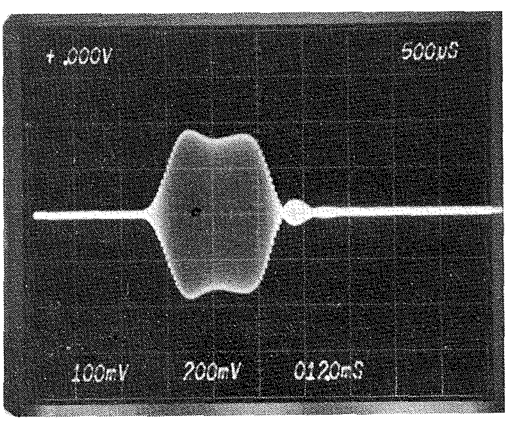

Fig. 6. Pulse number 1 measured at the calibrated output. Time delay: 12.0 ms. Scales: 200 mV/cm on vertical, 500 µs/cm on horizontal.

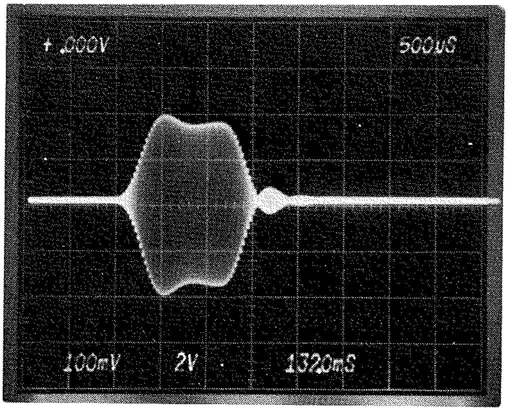

Fig. 7. Pulse number 10 measured at the calibrated output. Time delay: 132.0 ms. Scales: 2 V/cm on vertical, 500 µs/cm on horizontal.

VERIFICATION OF THE FREQUENCY

The frequency counter is coupled to the OUTPUT SIGNAL. The frequency should lie within ±10 Hz of the nominal value. The frequency is determined by the crystal CR2 and is not adjustable.

VERIFICATION OF THE ATTENUATOR

The switch HIGH/NORMAL is set in the HIGH position. The OUTPUT SIGNAL is coupled to the voltmeter and the signal strength recorded.

The switch HIGH/NORMAL is then set in the position NORMAL. The signal strength should be reduced by 20.0 dB.

If necessary, the attenuator can be adjusted by the potentiometer R45 on the signal generator printed circuit board.

COMPUTATIONAL EXAMPLE

In order to find TVG deviation at a specific depth, e.g., 175 m, the following procedure can be used:

Assume for definiteness that the echo sounder is of the EK 400/38 type, with $R = 581$ m and $\alpha = 0.008$ dB/m.

If the amplitude of pulse number 20 is 10 $V_{p\text{-}p}$, then the theoretical value at 175 m depth is

$$U_{175} = 20 \log \frac{10}{2\sqrt{2}} - (20 \log 581 + 2 \cdot 0.008 \cdot 581)$$

$$+ 20 \log 175 + 2 \cdot 0.008 \cdot 175 = 10.97 - 64.58 + 47.66 = -5.98 (\text{dB})$$

$$U_{175} = 2\sqrt{2} \cdot 10^{1/20(-5.98)} = 1.42 (V_{p\text{-}p})$$

The variable pulse is adjusted to 233.3 ms which corresponds to 175 m depth. If the read value were, for example, 1.34 V_{p-p}, then the correction factor for the integral at this depth is

$$1.42^2/1.34^2 = 1.12$$

which indicates that the integral at this depth must be multiplied by 1.12 to be correct.

N.B. For depths not exceeding 100 m, 20 dB must be added in determining the theoretical value.

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FOOTE, K.G., KNUDSEN, H.P. and VESTNES, G. 1983. Standard calibration of echo sounders and integrators with optimal copper spheres. *FiskDir. Skr. Ser. HavUnders., 17:* 335–346.

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