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"The Limitations of Integrated Circuits in Self-contained Underwater Equipment" by M.L. SOMERS, N.I.O.

There appears to be a clear trend in oceanographic instrumentation towards data collection by self-contained moored systems, which rely heavily on acoustic sub-systems for their operation. This is brought about by the need for both greater spatial coverage and longer time series of data; requirements which cannot be met economically by a manned vessel.

The N.I.O. has a number of projects in which equipment is reqired to remain in situ for periods of three months and eventually up to 1 year. It is believed at N.I.O. that highest rate of return in terms of data comes from sub-surface systems. That is to say a normally buoyant instrument package is ballasted with cheap material in such a way that the ballast can be released by acoustic command from the surface. No part of the system must break the surface or present a hazard to navigation during the period of deployment.

Of all the components of such a system the most critical is the power supply, for which a number of considerations lead us to use mercury primary cells for most applications, primarily their long shelf life and good discharge characteristic. But whatever supply is chosen it is essential to minimise the power consumption.

An essential feature of such a system is a clock and timing ligic with quite a high degree of long term accuracy, typically about ±1 part in 10^5 over 3 months and at first sight this might appear to be an ideal application for a crystal oscillator, 1C divider chain and gating system, to give sampling intervals ranging from a few seconds to several hours. However, with several decades of frequency division, such a system would necessarily consume quite large amounts of power, and perusal of the catalogues reveals that timing of this accuracy is possible with a transistor maintained mechanical excapement which will run for at least a year on a single V2 cell. Furthermore these clock movements cost only £9 in small quantities and have minute and hour shafts available with torques of ½ and 4 oz-ins respectively. It is probably fair to say that no all electronic system can at present compete with this in all aspects including price. There is however one 1C system which will out-perform the mechanical system on all counts except price. I will return briefly to this subject later.

Turning now, with apologies for having digressed, to the subject of self-contained acoustic systems, it can safely be said that all the functions provided by the cheaper forms of linear and digital 1C can, at the operating speeds required for underwater acoustic systems, be obtained at a fraction of the power consumption with discrete components. I will illustrate this remark by reference to a 10kHz transponder beacon developed at N.I.O. This is one component of an underwater instrument system, and is used for location of the system prior to recovery, so that the acoustic release system can be operated at short range with a more favourable signal to noise ratio.

The functional blocks of the transponder can be listed as follows:-

- Listening Amplifier
- Detector
- Gating Monostable
- Keying Pulse Generator
- Keyed Oscillator
- Power Amplifier

The first 5 items consume 1 to 1·5 mA at 6 v depending upon the interrogation rate. The power amplifier is supplied at 30 volts and draws a quiescent current of 3 times the 2N3055 leakage current which can easily be selected to be below 6 μA. There is of course no 1C power amplifier with a pulse output power of 200 watts, at present on the market.

The listening amplifier consumes about 250 μA and has a full voltage gain of 84 dB with a noise figure of about 3 dB and AGC range of at least 30 dB. To achieve the same performance with a linear 1C amp not custom designed would consume at least ten times the current. It is not in fact certain that the same noise figure could be obtained in any case with 1C's, for though we have no definite measurements, from our experience at N.I.O. we believe 1C's to be several dB noisier than good discrete component designs.

The various timing and logic circuits are easily implemented in any form of 1C logic and will save considerable space but again only at the expense of power consumption.

Enough has been said to show that though 1C's have a legitimate and very important place in underwater acoustics, when the system is self-contained the advantages begin to look much less convincing. Also we have found at N.I.O. that linear 1C amplifiers carry a noise figure that makes it inadvisable to use them in the front end of any low noise acoustic system, being several dB worse than a good discrete component design.

Finally I would like to return to the line of 1C's I mentioned earlier. Most of you will probably have realised that I refer to the line of complementary symmetry MOST. They are fairly new devices but at N.I.O. we already think they have a very important future. N and P channel enhancement type MOST's are connected in series between the supply rails. The gates are commoned and serve as the gate input. In this mode an OFF transistor serves as the load for an ON transistor so that the static current is typically in the nano-ampere range, and the power dissipation is

$P = Co\, V_{DD}^{2} f$, which is typically 5 μWatts per gate at 10 kHz.

A comparative test was made in which two discrete component divider boards were constructed specifically with power consumption in mind. They worked satisfactorily drawing 0·3 mA per decade from a 6 volt supply. A complementary symmetry MOST (seven stage) binary ripple counter (÷ 128) drew 2·5 μA from the same supply.

Various gating configurations are available and output nodes can when required supply or sink 2 mA without difficulty. Input thresholds are not well defined, but provided this is remembered input interfacing is very easy. Prices last March were £10 for a quad 2-input OR gate and £20 for the 7 stage binary ripple counter.