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# Digital processing of partial discharge signals

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With an interrupt routine the microprocessor's interrupt line is toggled and the processor is forced to stop whatever function it is performing at the time, and to jump to an interrupt handling routine. The use of interrupts in this application was problematic due to the fact that it takes between 20 to 30 micro seconds to service the interrupts and to execute the interrupt routine. This means that with this method it would take between 40 and 50 micro seconds to write a block of data to memory.

In polling, the microprocessor continually reads a data location and, when this alters, it jumps into the data gathering routine. The advantage of this method is that it is very fast, as the polling routine only takes a couple of micro seconds to run. There is a possible drawback to the polling approach, however, and this is that, if two consecutive discharges are of identical value, the microprocessor will not detect the second discharge as the data location will then be updated with the identical value, and thus no change can be detected!

The probability of this happening is naturally small, as tests using a test charge generator, which produced discrepancies of greater than +/- one percent from the mean, showed. If under laboratory conditions a test

charge can cause the analogue-to-digital converter to change in the least significant bit the chances are remote that ostensively similar discharges will not be detected. It was deceided to use the polling approach for this application.

The microprocessor is used in conjunction with a personal computer which communicates using an RS232-link. In this application the personal computer is used as a terminal as well as the long term storage medium for the programs of the microprocessor, which are downloaded when required.

The microprocessor has a FORTH compiler mounted onboard, and all programs used by the microprocessor are written in this language ( Incidentally, FORTH is not well suited to data manipulations, and it is envisaged as a future development to upload the data to the personal computer in hexadecimal form and carry out the data manipulations in an efficient high level language such as PASCAL.)

## 10 Testing of the System

The testing of the system consists of two parts:

a. Calibration.

b. Testing of objects known to give partial discharge activity.

The calibration was done using a Endaf Nonis charge calibration device, which produces test charges of 5, 50, 500 and 5C00pC, optically synchronised with the mains frequency.

In order to produce a calibration table, the voltage values produced at each of the test charges were interpolated (see Appendix B). This table was t. used to convert the voltage output of the device to the equivalent charge. Having drawn up a calibration table, comparative tests were carried out between existing analogue test equipment and the digital discharge detector.

A sharpened point placed in a spark gap can be used to produce discharges of a uniform charge.(4) A 0.5 millimeter point was available and this was used to produce discharges Using an ERA discharge detector this gives a discharge of 310pC. Using the digital discharge detector it was found that this device gave a discharge of 340pC's on a positive cycle and 300pC's on a negative cycle which is within +/-10 percent of the magnitude measured by analogue means.

A polyethelene sheet in which discharges occur was also available. This sheet produces discharges in the leading edge of the main cycle, this means that a group of discharges will be produced in the first and third quadrants of the mains cycle. The digital discharge detector satisfactorily detected these discharges, and found they produced a peak value of 240pC's.

The final test was carried out on a high voltage bus bar which has a known partial discharge activity. Comparisons between the ERA and the digital detector showed discharge was detected in the same portion of mains cycle, and that the characteristics of the major discharge activity was very similar.

One interesting observation was the fact that as the digital detector gave its results in the form of a printout, it was simple to discriminate between consecutive large and small discharges, whereas, because the ERA uses a cathode ray tube the smaller discharges were not easy to distinguish. Also if a large number of discharges occur closely-spaced, the ERA screen tends to blur them, whereas the digital detector allows them to be individually resolved down to 25 micro seconds.

## 11 Problems with the system as it stands

A number of problem areas emerged from the system

described thusfar:

a. Slew rate limitation.

b. Difference in operation of comparator circuits.

c. Programming limitations.

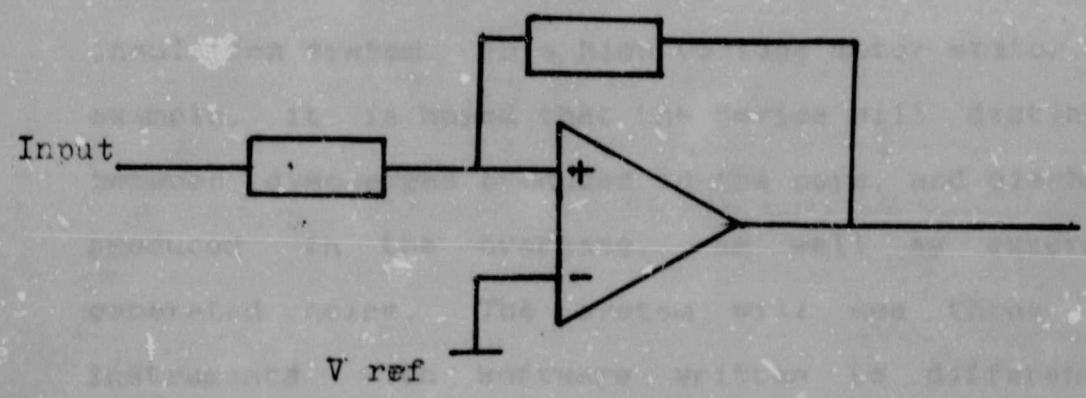
Since the peak value of the signal is referred to system ground, the entire input amplification system must be DC coupled. However,in DC-coupled operational amplifiers, drift becomes significant when amplifying small ( less than 10mV ) signals. Thus low drift operational amplifiers are required for the high gain amplifiers used to amplify the 1 to 10 mV signals. These operational amplifiers are unattractive due to very high cost. Since the rise time of the decaying sine wave produced by the resonant circuit is greater than 100V/ micro second, and the operational amplifiers used in the system have a rise time of 10V/ micro second, the amplifier does not track the input signal effectively, and the peak of the signal is chopped off, reducing the sensitivity of the device. The lower limit of the detector's sensitivity is poor. In order to increase the sensitivity, the input circuit was redesigned using components which slew faster.

A large number of comparator circuits are used throughout the design. There are two configurations used and these are shown in Figure 11.1. Both these use positive feedback, but the one with the input fed to the positive feedback component has a slew rate limitation which results in a difference in performance between the two. The device with the feedback tied to the voltage reference should be adopted throughout.

The programming of the system was limited by the fact that a readily available microprocessor system had to be used. In this application, a 68000 microprocessor with a FORTH compiler installed was used in conjunction with a personal computer. The microprocessor system can run machine code programs but there is no facility to up - load the data from the microprocessor memory to the personal computer memory. This means that the FORTH compiler, which was mounted in EPROM on the microprocessor board, had to be used for data manipulation. As this language is not well suited to data manipulations, a dedicated computer system should be designed to overcome these shortcomings.

## 12 Future developments

The system developed, in a redesigned form, is envisaged to be part of an instrument which would to



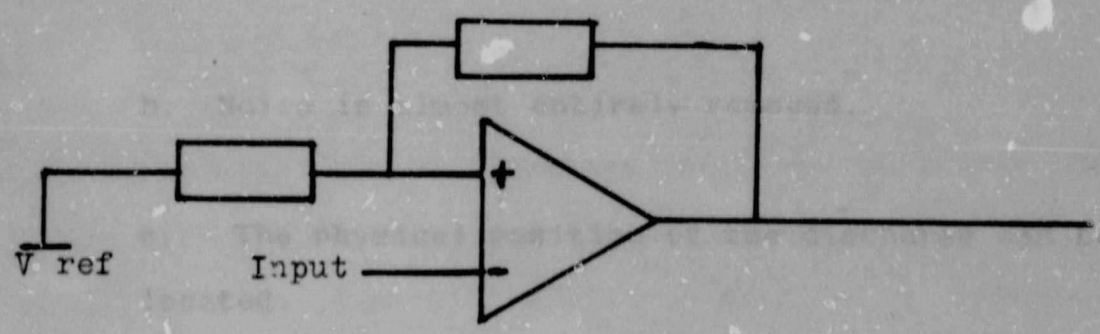




Figure 11.1 Positive and negative comparator circuits

detect the position of partial discharges within a large rotating machine where it could be used in order to isolate the partial discharge source in a complex insulation system. In a high voltage motor stator, for example, it is hoped that the device will distinguish between discharges produced in the core, and discharges produced in the overhang, as well as externally generated noise. The system will use three such instruments with software written to differentiate between noise and partial discharge activity. A system such as the one described above has the following advantages:

a. Sensitivity is optimised.

b. Noise is almost entirely removed.

c. The physical position of the discharge can be located.

I.A. Black (1) has developed a system which will measure partial discharges under noisy conditions, using two detectors, the outputs of which are combined via a correlation network to eliminate noise. The system has the drawback that the display is purely visual and that the position of the pulse within the machine cannot be determined. These two aspects will be eliminated, and a

noise reduction achieved, if three digital discharge detectors are combined with a controlling computer system.

The system described in this paper is flexible enough to be used for very low frequency testing of samples. In this testing, a cycle of 0.1Hz is applied to the system to allow resolution of individua' discharges in insulation situations with a very large number of discharges per cycle.

The speed of the detector is unaffected and hence the entire spectrum of discharges for one cycle can be stored.

## 13 Conclusions

An instrument has been designed here which records the value of the initial peak of a decaying sine wave produced when a partial discharge excites a resonant circuit, its polarity and time of occurrence. This allows a large amount of partial discharge data to be stored in a relatively small computer memory. The data contains all the relevant information required to reconstruct the discharge, since the peak value is directly proportional to the charge contained within the discharge. The instrument allows a discharge to be recorded every 25 micro seconds, which compares

favourably with present analogue technology.

A comparison can be drawn between the method used and that involving a full analogue-to-digital conversion. Full conversion, using a 16-bit analogue-to-digital converter, was not chosen because of the expense involved, since it encompassed both the analogue-to-digital converter itself, and the amount of memory required. The method chosen is clearly complex in execution, even though the basic idea is simple.

A qualification is difficult, however, because the linearity of the peak detectors and the sample-and-hold degenerates below 1V. If the peak detector and sample and hold could be designed to operate to the level of 0.1V, only two amplification channels, and not four could be used, halving the complexity.

Another useful comparison can be drawn between the method chosen and that of the full conversion of the entire signal. The advantages offered here are clearly of a financial order, while a certain amount of complexity becomes unavoidable. The hardware requirement has not been investigated for a full conversion solution, but the electronics involved are clearly not trivial! The circuitry needed to develop the control signals for the sample-and-hold, and analogue-to-digital conversion in this solution are themselves complex.

The solution chosen has been tested and found to store discharges in each of its amplification ranges. Even though there are a large number of components involved, and the system is a multi-channel one, the basic idea behind each channel is a simple one, and hence the operation of the entire system is relatively simple.

It is interesting to note that even very complex digitisers and storage oscilloscopes do not have the high speed data transfer capabilities of the system developed. It is possible that, because of these data transfer limitations little other work has been carried out in this field, and this development can claim to be significant.

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