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APPLICATION OF COMPUTERS AND MICRO PROCESSORS IN PROCESS INSTRUMENTATION

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MICROPROCESSOR-BASED SYSTEMS IN CONTROL AND DATA ACQUISITION IN PROCESS PLANTS, A QUALITATIVE APPROACH

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In the modern process control instrumentation the microprocessor-based systems are predominantly being used because of their simplicity and design standerdization of hardware and software. The implementation has been economically justified even in a small process of few control-loops as against the computer-controlled process of olden days.

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During the past twenty years, the automated process control industry has matured significantly. This is due to the introduction of the digital computer as an element of the control system. At the beginning of this period, the use of digital computer was limited to a supervisory status in which the actual control was performed by various combinations of relay, analog and pneumatic systems. Today, systems are off-the-shelf digital hardware and software to perform all the control applications. Indeed, the use of the hardware/software combination has opened entirely new areas of control applications. The significant increase in computer capabilities and the corresponding reduction in size has been accompanied by a substantial drop in cost. This has led to a strong incentive for users to employ computers in totally new application areas which have resulted from this change in economics. Twenty years ago, few computer control projects were initiated and these which were could only be justified economically in terms of control system which controlled upward of 100 loops. Today, a microcomputer system can be justified for a small process which contains as few as 3 or 4 control loops.

SC/MP was the first microprocessor by National Semiconductors which was extensively used in process control industry in diverse applications allocating the trend of process control technology towards digital electronics. The success of SC/MP was accounted for its application oriented design to the industrial standards which permitted its operation in harsh industrial environments. The break through of SC/MP into process industry was later followed by many other processors among them were intel, zilog, Texas, HP, etc.

GENERALISED COMPUTER APPLICATION AREAS IN PROCESS INDUSTRY:

Those applications in which computers are finding acceptance can generally broken down into two broad areas. The first envolves the acquisition and manipulation of process data by the computer, the second involves the manipulation of process itself called process control.

The majority of the acquisition systems involve measuring physical parameters of the process, for example, temperature, pressure, flow, level, etc. by suitable transducers to produce proportional voltage signal. This measurement is common for both data-acquisition and process control applications. In the latter, microprocessor interact with the process in order to manage it. This normally involves the activation and movement of a mechanical element which is incorporated into theprocess loop.

ALOG I/O BOARDS FOR TEMPERATURE DATA ACQUISITION - QUALITATIVE ANALYSIS:

A critical part of the temperature-controller hardware the analog input of temperature, because, until the gnal is digitized, it is susceptible to interference and ift. Consequently, the analog to digital conversion is rried out as early as possible and the rest of the strumentation, including the outputs is then purely gital.

When the number of temperature signals monitored creases to a large value, standard analong input/output ards available are the best solution for hardware and gnal conditioning. These boards have number of analog put signals, one selected at a time by the multiplexer; ter A to D conversion these are stored in the memory for rther processing. The actuating signal as a result of ocessing, which is in the digital form, is converted to analong signal by D/A convertors and delivered for ntrol of, for example, a valve on the fuel-line leading system which will control the fuel flow and consequently mperature of the process.

These boards come compatible to different type of bus nd the number of analog inputs vary according to require- ents. For a large size DAS (Data Acquisition System) hese boards consist of 70-80% of the system hardware, the dditional requirement is only a processor board, so alled single board computer, with processor chip, ports, onvolatile memory (EPROMS) to hold the system program, olatile memory for real time data storage and a clock.

Combining both input and output functions, the ombination analog I/O board, as indicated in Fig-1, enerally includes a data acquisition system, a digital o analog convertor, and a microcomputer interface tructure, which places all the circuit blocks under rogram control. In contrast, an analog input board contains just the data-acquisition system and its inter- face logic, while an output board has only a cluster of D/A convertors along with the required interface logic.

The data-acquisition system at the heart of an input board includes: a multiplexer, an instrumentation ampli- fier, a sample-and-hold circuit and an analog-to-digital convertor. These components operate under the command of on-board control and interface logic that automatically maintains the correct order of events. Under digital command, the multiplexer connects one of the input channels o the instrumentation amplifier. The input channel capa- ity can usually be expanded to accommodate hundreds of hannels by addition of necessary external hardware, nor- ally one or two standard analog input expander boards.

Depending on its input configuration, the multiplexer s either single ended or differential input mode. Single nded mode is suitable for applications where the signal evels are significantly larger than the common mode oltage present in the system. In the applications such as temperature signal input from thermocouple, where the signal level is only a few millivolts, differential signal mode is used although it halves the channel capacity for a particular multiplexer. There are multiplexing techniques which provide isolation through reed relays or optical couplers, so as to withstand hundreds of volts of common-mode voltage. Among its other features the multiplexer must have minimum on-channel resistence for better accuracy, typically it varies from 150Ω to 2.5KΩ.

Driving the multiplexer, the instrumentation amplifier provides impedance buffering, signal gain, and common mode rejection. To prevent errors due to loading this amplifier presents a high impedance - 100 Mega ohms or more to the analog input source. To increase the system sensitivity, amplifier boosts the input signal. The differential gain of most of these amplifiers may be programmed through software or adjusted with resistors, typically over a range of 1 to 1000.

Following the instrumentation amplifier and for driving the A/D convertor is sample-and-hold circuit, which freezes its output on receipt of a software command. So, although the input signal may continue to change, the A/D receives an essentially constant voltage throughout its conversion cycle. For the temperature monitoring applications, where the thermocouple or RTD time constant is of the order of a few seconds, the instrument amplifier signal will be reasonably constant in the A/D conversion cycle as the A/D conversion cycle is not more than few tens of micro-seconds, the S-H amplifier is not a requirement.

For the selection of accuracy of the DAS, resolution of the A/D convertor plays an important role. Resolution is usually 8, 10 or 12 bits with byte selectable data outputs. Most A/D convertors may be connected to deliver binary, offset binary, or two's complement codes. In terms of software, all these convertors generate a status bit which, depending on its logic state, signals either a conversion in progress or end of conversion. Unless operating in a free running mode, the A/D convertor requires a start command or strobe.

Since it is a peripheral, the input board imposes certain signalling protocol on the bus. For example the bus sends out the binary value of the desired channel to the multiplexer and starts conversion process. The bus must respond to the end-of-conversion signal from the ADC. Similar to input, an analog output board also serves as a peripheral with digital to Analog convertors (DAC) which deliver either current or voltage outputs. Fullscale outputs for individual DACs are jumper selectable for 0 to 10V, ± 5V and ± 10 volts. Current output version generally deliver the standard 4 to 20 mA and the output loading can range from 50Ω to 4KΩ.

In all respect, with broad selection of speed, sensitivity and isolation characteristics, analog I/O boards are keeping pace with the flood of new generation microcomputers, of more powerful instruction sets and greater computing power.

COMPUTER PROCESSING CAPABILITIES:

The key to the rapid growth of digital computers in process control has been the flexibility offered by the software. The hardware can be used in widely varying applications by allowing customerization through software programming. To be successful in process control applications, a digital computer system must be designed in a manner which optimizes the hardware/software relationships.

A powerful instruction set is mandatory if operations are to be performed efficiently by the processor. For complex arithmatics which is extensively used in process control, there are math. processors available, e.g. 8087 from intels which can perform floating point arithmatic and a wide variety of arithmatic and trigonomatric functions.

DEVELOPMENTS IN TEMPERATURE SENSING AND SIGNAL LINEARIZATION TECHNIQUES:

ESSENSE OF COLD JUNCTION COMPENSATION IN T/Cs:

When the hot junction of a thermocouple is maintained at the process temperature, the cold junction, which is normally terminated some where to recorder or indicator, located in the control room, may not remain at a constant temperature value because of the combined effect of heating produced by electronic components in the instrument and cooling due to air conditioning. Consequently the voltage which is proportional to delta 'T' across the T/C junctions will vary giving erratic results in process irrespective of the status of process temperature. So there is a need to neutralize these local variations of T/C cold junction temperature by some other agency.

There are many ways for cold junction compensation. An RTD bridge can be used which will be balanced at the zero degree C cold junction temperature and will produce an offset voltage at any other temperature value, this can be added with the thermocouple junction voltage after making adjustments for proportionality factor and isolation. In OEM products and standard analog input boards, semiconductor temperature transducers are used for this job. Semiconductor temperature transducer, for example, AD 590 or AC 2626 from analog devices produces a linear output current of 1.0 microamperes/°K. This can be manipulated with all the other temperature input signals to the acquisition system. The manipulation can be done at the hardware stage, before the multiplexer or later in the software after A/D conversion. The current signal transducers have the advantage that they are unaffected by the voltage drops and induced voltage along the transmission line and the signal can be carried to long distances without degrading the quality of signal.

THERMOCOUPLE LINEARIZATION BY INTERPOLATION TECHNIQUES:

All types of thermocouples generate some emf when there is a difference of temperature across its junctions. This emf is not a linear function of the differential temperature across its junctions. Consequently if same is used, asuming it linear, in control and data acquisition a significant magnitude of error is involved. The present day microcomputer system have solved this problem by what is called thermocouple linearization in which in computer's nonvolatile memory atable of T/C temperature and corresponding emf in digital form is stored so that any temperature value can be calculated for a given millivolts when required. For example, the entries are made for thermocouple linearization every 25 microvolts for a 50 millivolt range, this table will have 2000 entries. Further, each entry needs 2 bytes, so it requires roughly 4K memory. But this is quite an enconvenient formate for byte structured memory.

By interpolation techniques that would reduce the number of entries by estimating the function value in between, the same job can be done by a much smaller table and better accuracy.

Where accuracy requirement is not high, linear interpolation can be used but it causes errors by ignoring the derivatives of the function past the first. Second-order interpolation approximates the function with a quadratic, thus, better performance is expected (but not without more computations). To make the arithmatic simple it is important that there is constant spacing between the datas. The general class of interpolation formulas using constant difference is termed as "finite difference interpolation". Notation in the below given formulas uses the Δ (delta) or operator, defined as:

$$\Delta f(x_i) = f(x_i + h) - f(x_i)$$

also written as Δf_i. Second order differences are defined as

$$\Delta^2 f_i = \Delta f_{i+1} - f_i$$

and in general

$$\Delta^{k+1} f_i = \Delta^k f_{i+1} - \Delta^k f_i$$

A typical interpolation formula is Newton's forward interpolation:

$$f(x) = f_i + (x - x_i)\frac{\Delta f_i}{h} + (x - x_i)(x - x_{i+1})\frac{\Delta^2 f_i}{2h^2}$$

The second-order interpolation is reasonably good for all the applications of process control giving accuracies better than 0.1%.

IMPACT OF THIN FILM SENSOR TECHNOLOGY:

Advances in electronic signal conditioning and the need for better accuracy and stability have been responsible for thermal hysterisis in RTD sensors. Also, while all three types of RTDs - wirewound, thick film and thin film - have become more stable and accurate, thin film sensors are making a major impact on the sensor market. Ideal for use in microprocessor-based products, they are being used to replace thermocouples in many applications.

With the use of microprocessors, error in the RTDs ue to thermal hysterisis can be brought down to minimum f the order of 0.04%. The importance of identifying ensors with poor thermal hysterisis demands upon the ntended use when the temperature range is small, or the easured temperature is at the either end of the sensors ange, thermal hysterisis will have little effect on the verall accuracy. Conversely, when the measured tempe- ature range is wide or the thermal history of the sensor s unknown, the hysterisis can be a major source of error.

The thin film RTDs have two major areas of applica- tion: OEM products and fast-response control systems. For OEM's, their low cost and excellent accuracy make them ideal for use in microprocessor-based industrial contro- lers and readouts. Also, the thin film RTDs offer a ight weight low mass package which is very competitive with thermocouples.

In conclusion, the recent entry of microprocessor based systems into a broad field of process control applications is substiating the billing as a "Super-compo- nent". Single board computers provide a solution to several problems that have not been solved by the use of conventional computers: cost, size and design specilization.

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