Applications report

APPLICATION OF CMOS TECHNOLOGY TO PROCESS INSTRUMENTATION: SOME CASE STUDIES

Indexing term: Instrumentation

Abstract: The paper considers the application of CMOS technology to process instrumentation and gives examples of the use of CMOS in design.

Introduction

This paper discusses the reasons why CMOS is a desirable technology for some process instrumentation applications. Some examples are described which use CMOS exclusively in the design, giving the reasons why CMOS was used and the problems that were found while developing these instruments. All these examples are joint developments carried out by Sira Ltd. and a manufacturing company.

CMOS technology can be applied to advantage in process instrumentation, but the designer who is more familiar with NMOS and TTL devices must take into account the lower speed of CMOS components as compared with LS and NMOS equivalents, must avoid 'latch-up' conditions, and should apply all the normal design rules for LS and NMOS to the CMOS design.

Why choose CMOS for process instrumentation?

The growing use of CMOS components for process instruments is due primarily to the low-power requirement of the technology. The advantage of using low-power components is that it is far easier to design intrinsically safe and battery-operated instrumentation. Intrinsically safe instruments are essential for the energy industries (oil, gas, coal etc.) and for some process industries. The reliability of process control and measuring instruments is increased by being able to site the instrumentation in the hazardous environment, as opposed to relying on sensors connected by long lines to a remote instrument house. There are also ergonomic advantages in being able to install intelligent instruments close to the process under control. The main advantage of battery-operated instruments over traditional instruments which require a local supply is that they are portable. Portable test equipment can be carried onto site and used for on-site maintenance. Portable data logging and remote monitoring and control equipment can be installed in hostile environments for long periods of time, and collected only when necessary.

Some product examples

Sira has worked with a number of different companies on the collaborative development of various CMOS-based instruments over the last few years. The product examples discussed below are:

Gas flow volume corrector (Fig. 1)
BS Instruments Ltd.

System for tanker instrumentation and control (Fig. 2)
Drum Engineering Ltd.

Temperature readout for a hand-held thermal imager (Fig. 3)
Lasergage Ltd.

Gas flow volume corrector

The model 800 volume corrector jointly developed by BS Instruments and Sira is a battery-operated portable instrument that is now in large-scale production. The corrector is intended for use by industrial consumers of natural gas. Uncorrected flow rate is measured using a turbine meter. The static pressure and temperature are transduced and used to determine the gas compressibility factor, from which the true corrected volume flow can be calculated at a standard temperature and pressure. The corrector is intrinsically safe, and can be sited by the gas supply inlet.

The processor used is the Motorola 146805. This processor, as well as handling the analogue and pulsed turbine input, is also capable of performing the calculations required to determine corrected volume flow. A particular advantage of this device is the 'go to sleep until interrupt' command, which is used to prolong the battery life.

System for tanker instrumentation and control

Development of the DRUM-STIC was achieved through a four-way collaboration between Drum Engineering, Marconi, Sira and The City University. The product is a multiprocessor system consisting of satellite processors that measure the fluid volume in the separate compartments of a road tanker, and a central controller.

The level transducer is a vibrating rod developed by Marconi. The local intelligence that converts the frequency, density and temperature data into volume is a Motorola 146805-based single-board computer, developed by Sira and Drum Engineering, sited above each tank. The data from these satellite volume monitors are transmitted to a central controller based on a CMOS 8085. The central controller is responsible for interrogating the volume monitors, monitoring the front panel, driving the displays and controlling the tank valves.

Fig. 1 Gas flow volume corrector
[BS Instruments Ltd.]

The complete system is intrinsically safe, and operates from the road

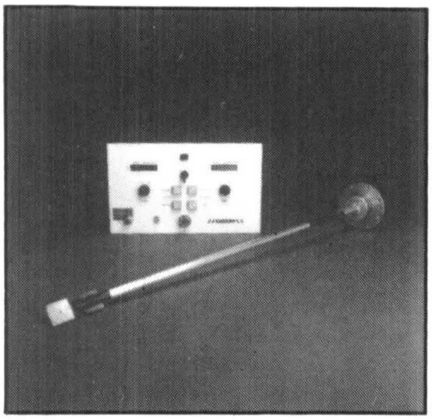

Fig. 2 System for tanker instrumentation and control
[Drum Engineering Ltd.]

tanker's on-board battery. This application demonstrates another advantage of CMOS technology, in that it will tolerate a wide range of operating voltages and does not necessarily require highly stable supply voltages.

Temperature readout for a hand-held thermal imager

Lasergage manufactures a range of portable hand-held thermal imagers. A thermal image of process plant is of great advantage for locating possible failures in the plant. For example, a weak point in a furnace or a high-voltage transmission line will be clearly seen as a 'hot spot', and preventative maintenance can be carried out. The imager must be portable and therefore runs off batteries. Hot spots are a major hazard in the gas, coal and oil industries, and an intrinsically safe, portable thermal imager will help to make their process plant safer to operate.

Sira assisted with the development of a temperature readout facility for the imager. By measuring the signal from the infra-red detector, and a reference temperature, and then applying a complex algorithm, the temperature of the target being viewed can be determined. The target temperature is displayed in the lower band of the thermal image. The readout must be intrinsically safe and battery operated, and was therefore developed using an NSC 800 and CMOS components.

Problems arising during development

Four main problems arose as a result of using CMOS components: speed, power surges, 'latch-up' and failure to power on reset.

Speed

Standard 4000 series and 74C series devices have much longer switching times than their TTL equivalents. Fig. 4 shows a circuit which demonstrates the problems that can arise. The decoder part of the circuit is used to select the I/O map of an NSC 800, CMOS 8085 or equivalent. The output latch is only selected during a write operation. This circuit was found to be adequate on a processor system running at up to 4 MHz, but any attempt to run it faster failed. A quick examination of the worst-case gate delays gives the reason. Each NAND gate has a typical delay of 125 ns each, the OR gate takes 160 ns, the decoder takes 550 ns to settle and the set-up time for the latch is 220 ns, giving a total typical delay from address set-up to chip select of 1180 ns. The write cycle of an 8085/NSC800 is only 990 ns when running at 6 MHz. The solution to this problem, and other more subtle timing problems, is to use high-speed CMOS devices, such as the Signetics HEF series, or the 74PC

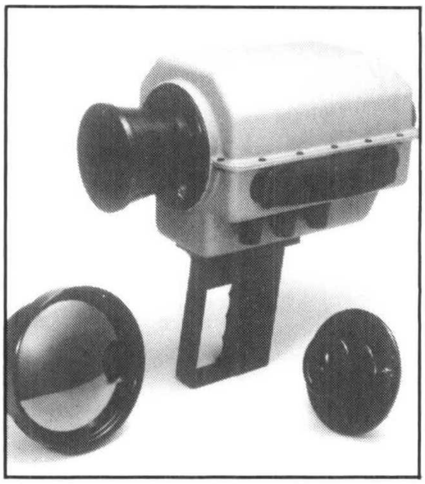

Fig. 3 Hand-held thermal imager
[Lasergage Ltd.]

(National) and 74HC (National, Motorola) devices which approach TTL speeds.

Power supply spikes

Just because CMOS technology takes less power than other equivalent technologies, it is incorrect to assume that it does not generate current surges and therefore voltage drops on supply lines. Fig. 5 shows two traces taken from a 27C32 CMOS EPROM under maximum switching load. One trace is the output enable input signal; the other is a data output line. The bus is the multiplexed address/data bus of a CMOS 8085. The address is FF hex and the data is 00 hex; therefore the output buffers of the 27C32 are required to perform the maximum switching load pulling a set of bus lines all set high to their low states. Despite the fact that the device is CMOS, the current surge generated when the output is enabled is sufficient to put a 1 V spike on the supply lines. As a result the device switches off and the data disappear. This problem was cured in the final prototype by the addition of a more substantial power gridding network on the PCB. This is of course good engineering practice. However, the lesson to be learnt is that, despite CMOS's low power consumption, it is still capable of generating large switching spikes.

Latch-up

CMOS, owing to its construction, inherently has parasitic SCR junctions that in normal operation are reverse biased. If input signals exceed the power supply then these junctions become activated, causing SCR latch-up and allowing high currents to pass which will easily destroy the device. Sensible design can ensure that a latch-up does not occur, the easiest method being to employ level-shifting devices at input interfaces. A particular problem arose with a fast rising power supply that put some ringing on the supply lines. As a result, on power up

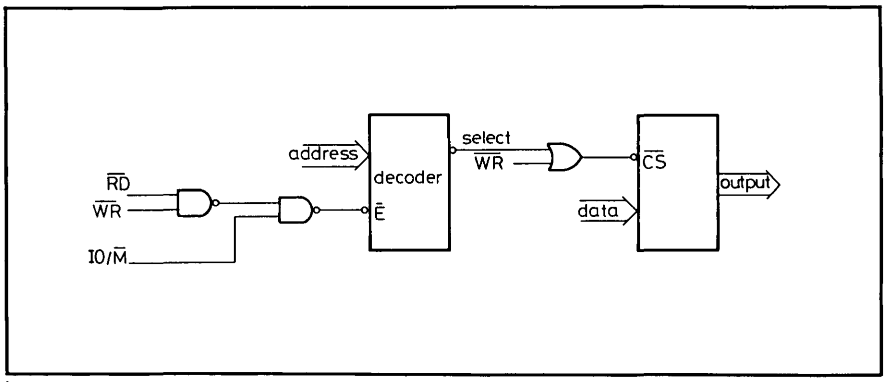

Fig. 4 Address decoding for CMOS 8085

the CMOS processor invariably went into a latch-up mode. This was cured by adding extra decoupling to the supply lines.

Power on reset

A phenomenon that was discovered with a variety of processors was their failure to start their clocks oscillating on power up. As yet the cause has not been firmly established. The solution is to use an active reset device, such as the 4541, with a long time constant, and not rely on an RC network.

Conclusion

CMOS-technology components can be used in the engineering of process instruments. The design rules for CMOS-based instruments are more complex than those for NMOS and TTL instruments. This is because the engineer has not only to apply the same rules required for NMOS and TTL, but has also to take into account the additional rules that apply to CMOS.

E.N. GOODYER *3rd May 1984*

Electronics & Computing Systems Department, Sira Ltd., South Hill, Chislehurst, Kent, England

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Fig. 5A Data output from 27C32 showing 1V switching spike on RD line

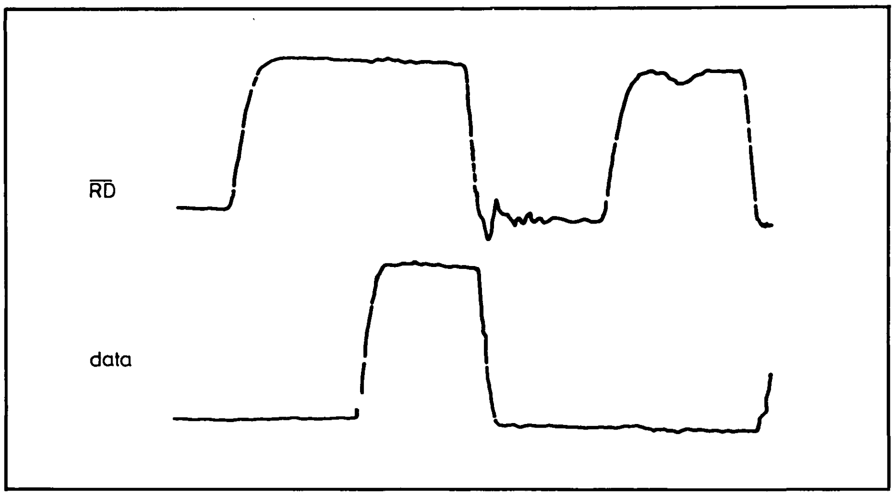

Fig. 5B Data output from 27C32 with correct PCB power gridding

Book review

Designing systems with microprocessors — a systematic approach
D. M. Freedman and L. B. Evans
Prentice-Hall, 1983, 332pp., £28.75
ISBN: 0-13-201350-9

About a decade ago, in the early days of the microprocessor, it was the custom for logic designers to attend courses to introduce them to the new device. If the subject of top-down design was mentioned at all it was touched upon only briefly. Indeed, the object of the courses was to allow the participants to start producing code as quickly as possible, with a little perfunctory testing if time permitted. It is sobering to consider how much randomly designed code (with its attendant bugs) must exist to this day in assorted control systems around the world.

Fortunately, the past few years have seen an increased awareness of the need for a more structured approach to system design. Today, the terms 'top-down design' and 'software engineering' are commonplace. In keeping with this trend, the book by Freedman and Evans provides a welcome new variation upon the 'introduction to microprocessors' theme.

This attractively presented book is aimed at undergraduates and at practising engineers. The structure of the book reflects the 'top-down' nature of its subject. Anyone raised on more conventional microprocessor texts will be intrigued that the first five chapters of this book contain no mention of arithmetic logic unit. However, it is this lack of obsession with minute detail in the early chapters which makes this text so refreshing. Similarly, whereas most books dive directly into assembly language, the emphasis here is on the high-level language PL/M. Details of hardware and assembly language are covered later, only after the more abstract concepts have been established.

In keeping with its subject matter, the book itself is well structured: the authors present a diagram showing the relationship between the system design cycle and the chapters of the text. The reader is led from requirements definition, functional specification and system design, through hardware and software design and implementation, to system integration and evaluation. Continuity is provided by the use of a running example — a burglar alarm system.

Chapter 1 leads in gently with a discussion on the