# LOW COST SENSORS TECHNOLOGY AND APPLICATIONS

Mackintosh
STATE OF THE ART
Series

BENN
ELECTRONICS PUBLICATIONS

# LOW COST SENSORS TECHNOLOGY AND APPLICATIONS

Mackintosh STATE OF THE ART Series



PUBLISHED: Benn Electronics Publications Limited February 1983

ISBN: 0.904705.51.X

Benn Electronics Publications Limited
PO Box 28
Luton LU1 2NT
Tel: (0582) 417438
Telex: 826314

PREFACE

Low Cost Sensors - Technology and Applications is one of the Benn Electronics Publications "STATE-OF-THE-ART" Series.

The STATE-OF-THE-ART Series aims to inform in particular technical, design, application and research management in the electronics and related industries, of the current status and likely future trends of growth technologies where commercial opportunities exist now or are fast developing.

The report was written for Benn Electronics Publications Ltd by Mackintosh International, one of the world's leading consultancy groups specialising in electronics.

Other titles in the STATE-OF-THE-ART series include:

- Semi-Custom ICs - The Proceedings of the First International Conference
- Advances in Electronic Components & Systems
- Gallium Arsenide: Materials & Devices
- Internepcon UK '82
- Memories Technology and Applications

Benn Electronics Publications Ltd is a subsidiary of Benn Brothers plc, the major UK trade and technical publishing house established in 1880.

February 1983

## PART I SENSOR TECHNOLOGY

## PART II - SENSOR APPLICATIONS

## FIGURES

# 1. INTRODUCTION

A sensor is defined as a device which converts a physical parameter into an electrical signal. With the rapidly falling costs of microelectronic circuitry have highlighted the need for lower cost sensors.

It is also evident that electronic controllers are gradualy replacing electromechanical ones, and the input signals to the controller are provided by sensors.

Until recently, sensors have been specialized, high cost, virtually custom engineered devices, designed for the quality conscious process control industry. Volumes have been low and prices in line with the rest of the control system. However, advances in the semiconductor industry have improved the price/performance ratio of electronic circuits by a factor of $10^{12}$ over the last twenty years and the availability of low cost microprocessor controllers has meant that now sensors may frequently represent the highest cost of the system.

The widening gap between the cost/performance ratio of the controlling electronics and that of the sensor has been realized and there is now considerable activity to produce low cost, microelectronic compatible sensors.

This Benn Electronics Publications State-of-the-Art report examines the technology of and applications for low cost sensors.

The report is split into two parts: Part I Technology and Part II Applications.

Part I examines the technology of sensors and, where applicable, where technological change would be advantageous. Particular attention has been given to the impact of microprocessor on sensor requirements.

Part II is particularly detailed, scanning the applications by major category, e.g. Consumer, Medical etc., and by specific application, e.g. Microwave Ovens, Washing Machines, etc.

## 2. SILICON SENSORS

There is a great deal of research and development activity in the field of silicon sensors. The widespread interest is due mainly to their compatibility with microelectronic circuitry, their small size and potential for mass production and low cost.

The well developed semiconductor manufacturing technology offers many novel solutions to the problems of sensor design, including on-chip circuitry for signal conditioning and the ability to fabricate more than one sensor on a single circuit. As they are small, silicon sensors can be physically located virtually anywhere and they have only a small influence on the parameter being measured.

The properties of silicon enable it to transduce most energy forms and can therefore form the basis of many different types of sensors. Silicon sensors are available which measure pressure, temperature, flow, position, optical, magnetic and chemical activity.

The manufacture of silicon devices in high volume is well established. This makes silicon particularly appealing as a sensor material, but the same manufacturing techniques can be used with other materials.

Many of the techniques developed for the high volume production of microelectronic circuits, such as photolithography, etching, automatic batch manufacture and testing can be applied to the manufacture of silicon sensors, giving small size, with accurately controlled geometries and the ability to mass produce a silicon sensor at a potentially low cost. Indeed, the low cost multiple sensor array is a distinct possibility in silicon technology. Optical arrays are already in existence. However, there are market opportunities for chemical sensor arrays for use in pollution monitoring and pressure arrays for use in robotics.

The basic sensing mechanism is frequently only a small proportion of the cost; testing/calibration and packaging are very important factors. Packaging costs can be extremely high, especially if the sensor has to withstand the harsh environments of corrosive chemicals, shock and vibration etc.

Testing and calibration must also be automated in order to achieve low costs. Ease of testing often depends on sensor design. For example, the Motorola and Honeywell chip carrier system used in their pressure sensors enables the sensors to be tested automatically and calibrated without difficulty.

### Integrated Signal Conditioning

An important factor in low-cost production is the ability to integrate the signal conditioning circuitry and control electronics into the silicon sensor itself. This would decrease overall system cost and increase reliability.

Most types of sensor need some form of signal conditioning circuitry to convert the signal they produce into a form which is useful to the electronic controller. The signal conditioning may involve linearization, amplification, conversion into a current or voltage of the desired level, digitization, compensation for second parameter effects, etc.

As these circuits will be fabricated in silicon anyway, it seems an obvious step

to incorporate them into the silicon sensor itself, as shown in Step II of Fig.1. This will not significantly increase the size of the silicon sensor, but would increase its complexity and therefore is likely to decrease its yield. However, this would only slightly increase the cost of the sensor and this would be more than offset by the considerable saving in overall system costs. Also fewer soldered connections also improve reliability. This has already been accomplished by the manufacturers of integrated temperature sensors.

### Multiple Sensors

The compensation of secondary parameters effectively means two sensors in one package. This concept could in theory be extended to provide sensors that measure more than one parameter. Multiple sensors are likely to be developed for specific applications rather than as a 'general purpose' component.

Active compensation of secondary parameters is already performed in semiconductor pressure sensors, where a temperature sensor is incorporated into the silicon circuit to compensate for temperature-induced errors.

The concept could be extended so that a single sensor is able to measure more than one parameter. For example, a pressure sensor and a temperature sensor can be combined in one package. Another example of a combined package could be a flow sensor and a temperature sensor.

Applications for multiple sensors exist in virtually every industrial sector. For example, there is a requirement in the process control industry for multiple sensors in order to reduce installation costs.

A combined temperature and humidity sensor has been developed by Matsushita. This ceramic sensor should provide a more cost effective solution to the heating industry, where both temperature and humidity frequently need to be measured.

Another application could be in washing machines where a combined temperature and pressure sensor could be used for monitoring water level and water temperature.

However, variations in packaging, range and performance make it difficult enough to fabricate a sensor which will serve more than one application, and these problems are exacerbated with multiple sensors. In addition, the optimum position for location of the sensor may even be different.

The multiple sensor would have limited potential sales as the costs would preclude development without high volume applications.

### Digital Output

Sensors with a digital output give improved data transmission characteristics and compatibility with digital systems. This can easily be achieved using on-chip circuitry.

A number of different industries have expressed the desire for sensors with a digital output. The automotive industry would like digital output sensors, provided their cost and performance are comparable with current designs. There are two main factors: the increased reliability of data transmission due to the inherent noise immunity of digital signals, and compatibility with the growing number of digital controllers being used.

# FUTURE DEVELOPMENT TRENDS IN SENSORS

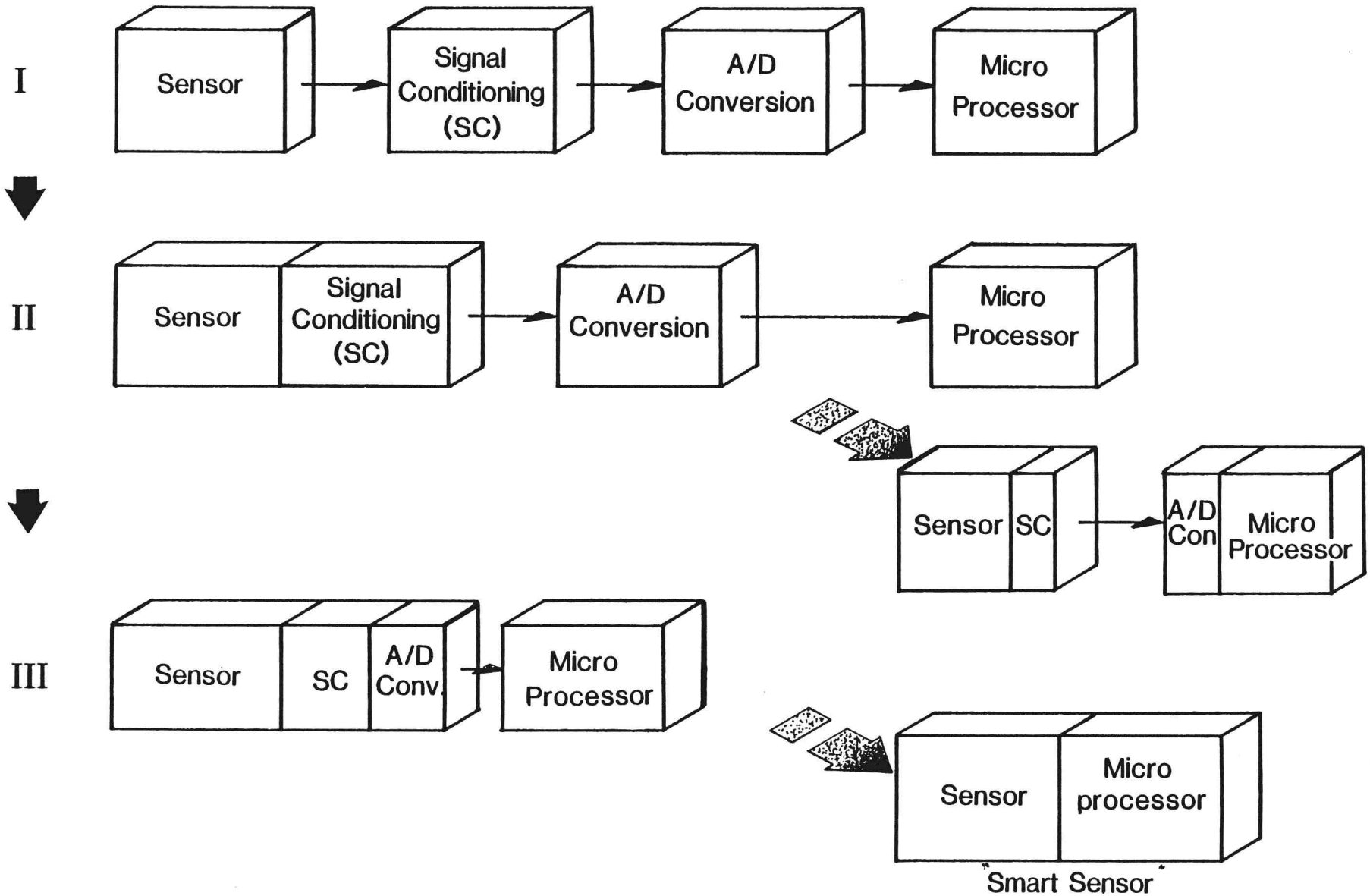


Fig 1