Development of a water leak detection system

by H. J. Convey and M. J. Booth

Water leak detection systems are a specialist service applicable in sensitive areas and important buildings. They provide early warning of leaks and thus help to prevent damage to equipment and buildings. These are often in areas of uninsured risk. This article describes a TCS Programme to develop a new microcontroller system, its basic operating principles and the benefits to the company.

The aim of the TCS Programme between Bolton Institute of Higher Education and Andel Ltd. was to establish a Research and Development Group within the company. The objective was to develop a new range of water leak detection systems to augment the company's existing product range that was initially designed using third-party contractors.

Andel designs, manufactures and markets water leak detection systems to warn of potentially damaging leaks from pipes and other water services. These systems are installed in sensitive areas and important buildings. Liquid leak detection is a specialist service applicable mainly in areas of uninsurable risk. The industry is around ten years old and the market was served by simple and often limited equipment. At the start of the project, the major supplier, thought to have at least 50% of the UK market, was a US company and Andel estimated its own market share to be around 15%. The TCS programme was to design a new generation of innovative products to stimulate market growth while strengthening the company's current and future market share. There are no recognised standards for leak detection systems, and the new system would establish a 'benchmark' by which the market could set higher expectation levels and measure comparative performance.

Bolton Institute is the DTI 'Microelectronics in Business' (MIB) and 'Electronics Design' (ED) Support Centre for the North of England working with small companies to develop new products and processes. Using this framework, feasibility studies with Andel established the rationale for the strategic development of a new range of water leak detection products. The TCS programme ensured that effective technology transfer into Andel was achieved with consequential enhancements of its staff, turnover and profit margin, thus strengthening the company's image as a proactive innovator.

Andel leak detection and alarm systems

Andel leak detection systems are designed for all types of buildings and installations. Leaks are common, and if allowed to continue unchecked can cause extensive damage, disruption and loss. The Floodline range of leak sensors and systems provide the following benefits:

- Is easily installed and used in sensitive or critical areas to give early warning of a leak from any source.
- Early action can be taken to prevent damage, reduce disruption and limit loss.
- Zoned systems that are flexible, accurate, easy to install, use and maintain.
- Zoned systems offer the best cost/benefit option for any application, large or small, complex or simple.
- Includes a range of leak detection cable, different types of point sensors and a variety of single and multi-zone controls.

Fig. 1 indicates the range of system components. The original eight-zone multi-zone control panel is also shown.

These systems have many and varied applications, being installed in:

- modern offices
- call centres
- historic buildings
- communication rooms
- dealing rooms
- telecommunications and switch centre etc.

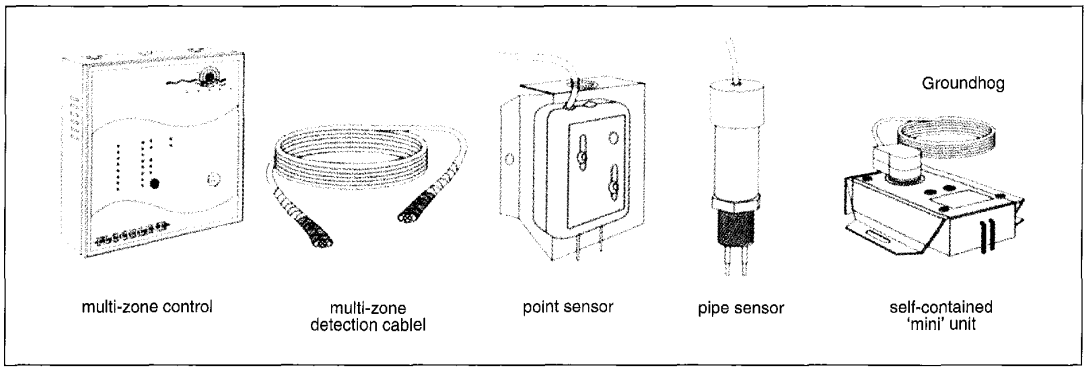

Fig. 1 Range of system components (courtesy of Andel Ltd.)

Purpose of the TCS programme

Andel needed to improve its technical capabilities by creating its own research and development capability to match the entrepreneurial strengths of the management team. The TCS programme also addressed the limitations of the existing designs to provide a system with:

- enhanced zone capacity
- increased system flexibility
- the ability to communicate with building management systems (BMS)
- a graphic user interface for building managers to observe alarms and manage the system
- remote data logging for trend analysis and fault location
- remote configuration of system performance characteristics.

Fig. 2 shows a typical computer room installation. The computer room services (air conditioning, cooling water, radiator supply, water supplies for vending machines, waste pipes, cable trays, power distribution etc.) are routed through ceiling or false floor voids to provide a clutter-free environment. In these voids the onset of water leaks will not be readily apparent until consequential damage causes a secondary failure (corrosion of metallic parts, short circuit of cabling, structural damage to the building due to damp penetration etc.) in the operational area or wide-scale water flooding.

As an illustration the multi-zone leak detection cable has been laid in the ceiling and floor voids underneath pipes containing water for the services needed in the computer room. These leak detection cables are connected to junction boxes that allow the cable to be split into specific zones, enabling the Floodline system to

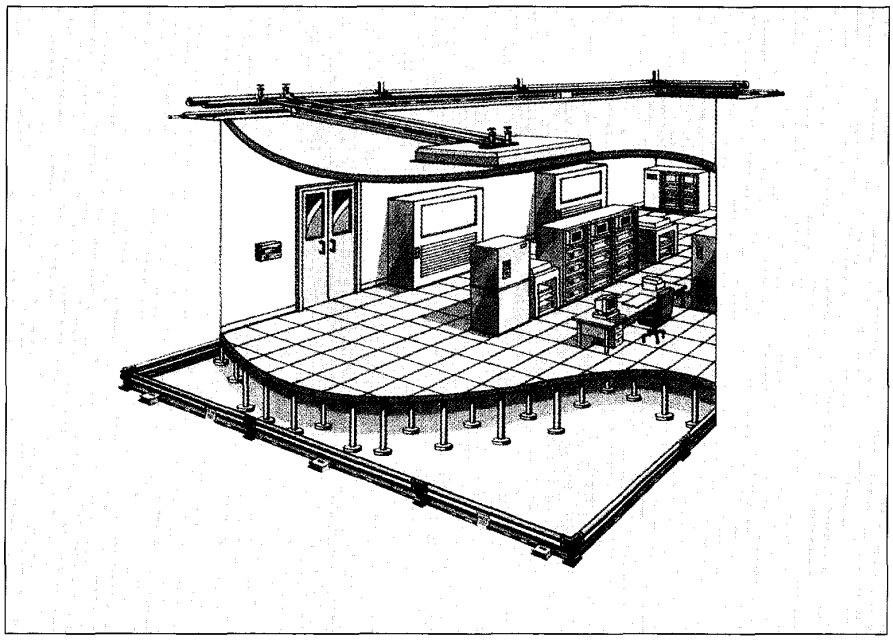

Fig. 2 Typical computer room configuration (courtesy of Andel Ltd.)

identify the exact location of a water leak. When a leak is detected audible and visual alarms are sounded locally, in this case on the control unit situated to the left of the double doors.

Basic principles

The detection technique uses a textile based water absorbent detection cable. The resistive characteristics of the cable are such that a dry cable has a resistance of greater than 4MΩ between two cores. As the detection cable absorbs water the resistance is reduced. Fig. 3 illustrates the measurement system comprising the detection cable, a termination resistor, a pull-up resistor and ADC for voltage measurement. This forms a potential divider network and the resistance of the detection cable can be calculated:

$$R_{cable} = \frac{R_p \times V_{adc}}{(V_{cc} - V_{adc})}$$

where R_{cable} is the resistance of the cable (including the termination resistor, typically 1MΩ), R_p is the value of the pull resistor, V_{cc} is the supply voltage and V_{adc} is measured voltage across the cable.

If an 8 bit ADC is used with suitable resistor values the equation for calculation of the cable resistance can be simplified to (value in kΩ):

$$R_{cable} = \frac{100 \times V_{adc}}{(255 - V_{adc})}$$

where V_{adc} is the ADC input voltage represented as an 8 bit number in the range 0–255. This equation is easily implemented in the microcontroller. Using the calculated value of R_{cable} the condition of the monitored zone is banded as shown in Table 1. This banding allows the system to detect fault conditions on the installed detector cables. Damage to the cables subsequent to commissioning is normally presented to the monitoring system as either a short or open circuit. By splitting the detection system into zones a number of benefits are achieved:

Table 1 Condition of monitored zone

R_{cable} resistance	condition
<20kΩ	cable short circuit fault
<300kΩ (leak threshold adjustable)	leak detected
300 kΩ to 1·25 MΩ	no leak detected
> 1·25 MΩ	cable open circuit

- Each zone is separate—an alarm in one zone has no affect on the normal function of the rest of the system.
- Each zone is continually monitored for either a leak or system fault.
- 'Mix and match' different types of sensors from zone to zone.
- True multi-zoning—the system can handle, display and report any number of simultaneous alarms.
- No minimum or maximum zone length or size.
- Separate outputs/communications can be provided for each zone.
- Alarm prioritisation for important zones.
- Better control of costs through choice of zone size.
- Easy to service.
- Easy to configure to individual current and future needs.

A larger number of small zones allow better definition of the flood area. Andel's existing maximum control panel size was limited to 16 zones. The growing demand for extensive multi-zoned systems in large buildings could only be satisfied by a cumbersome and unsightly group of several control panels and an unacceptable network of leader/carrier cables.

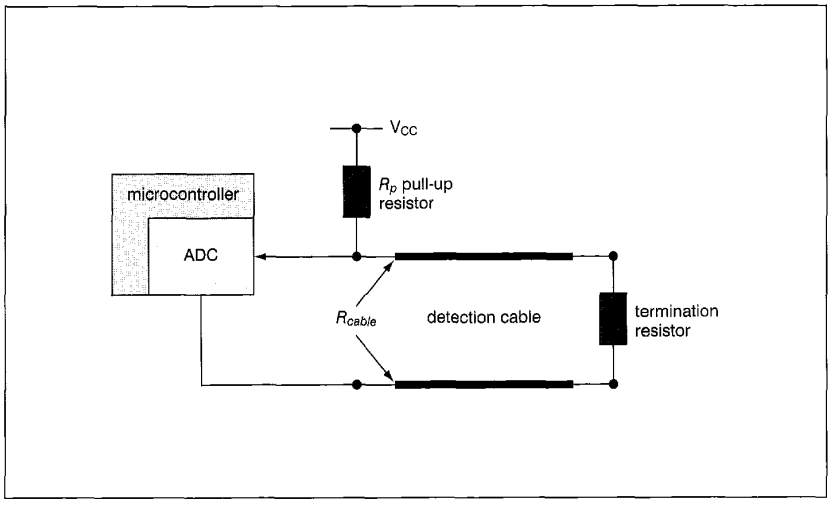

Fig. 3 Basic measurement system (courtesy of Andel Ltd.)

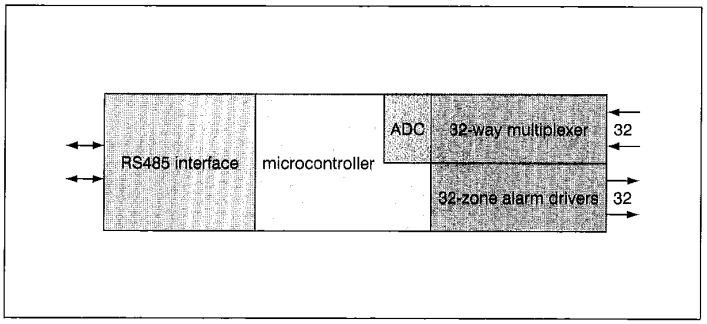

Fig. 4 32-zone card (courtesy of Andel Ltd.)

What innovation has taken place as a result of the TCS Programme?

The innovation required was to design a new control system with a much larger capacity-up to 128 zones with the following features:

- Reliable in terms of preventing false and spurious alarms.
- Flexible to cope with wider site variations, background damp etc.
- An easy operator interface that was smaller and aesthetically acceptable
- A new detection cable less sensitive and quicker to dry (using semiconductive polymers instead of textile materials).
- Use less peripheral leader/carrier cabling (and thus cheaper to install).

The outcome was the Floodline 128. To achieve the maximum capacity of 128 zones, the zones are monitored in four groups of 32. A 32-zone card is shown in Fig. 4.

In the 32-zone card a multiplexer is used to sequentially select each of the zones and the microcontroller then acquires the zone voltage. A zone has a voltage applied to it for a short period of time, thus reducing the adverse effects of electrolysis when the sensor cable is held within a water leak. The microcontroller holds the current value of all the monitored zone voltages and reports them back on demand via the RS485 communication protocol to the control unit. An optional relay driver card can provide individual alarms. The status of the individual alarms is determined by the control unit and sent to the relevant 32-zone cards via the RS485 communications interface. The modular structure of the zone cards enables the system to be updated to incorporate new zone sensing techniques without major reconstruction of the system. Fig. 5 shows the flexibility of the Floodline 128 system to have a range of detection cable and point sensors.

Fig. 6 is the block diagram of the Floodline 128 system. Each module in the system has its own microcontroller and communicates with other modules in the system via the RS485 half duplex communication network that has a Modbus protocol to ensure the integrity of data communications.

The control unit has different security levels to provide access to programming functions, resistance log, sensitivity adjustments and current activity throughout the whole system. The control unit is configured as the master unit in the system and consists of an LCD, a keypad, non-volatile memory for configuration data (leak threshold values for each zone and plain language text to identify zone for presentation on the LCD), non-volatile memory (fault reports and resistance logging) and a sounder for audible alarms. The configuration data and zone identities can be entered via an engineer mode on this unit using the keypad and LCD display for simple on-site changes. An RS232 serial communications port enables the configuration data to be up and

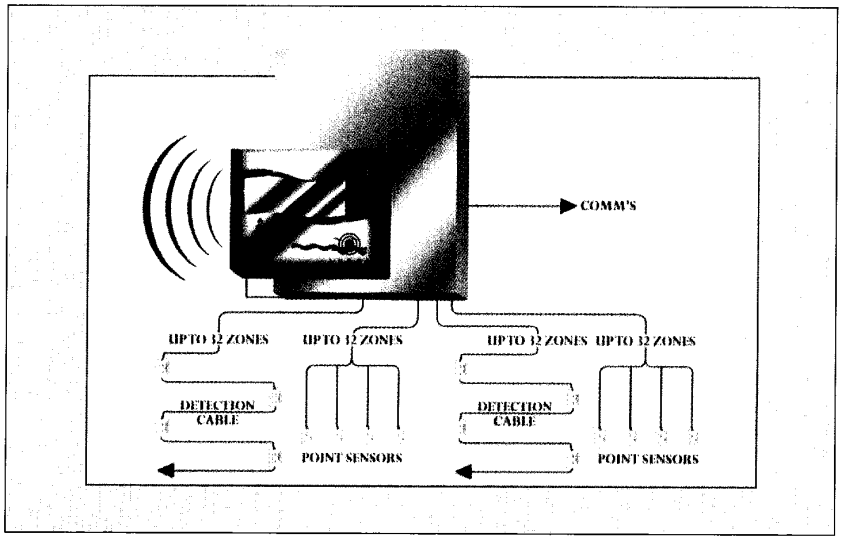

Fig. 5 Floodline 128 illustrating possible combinations of sensors (courtesy of Andel Ltd.)

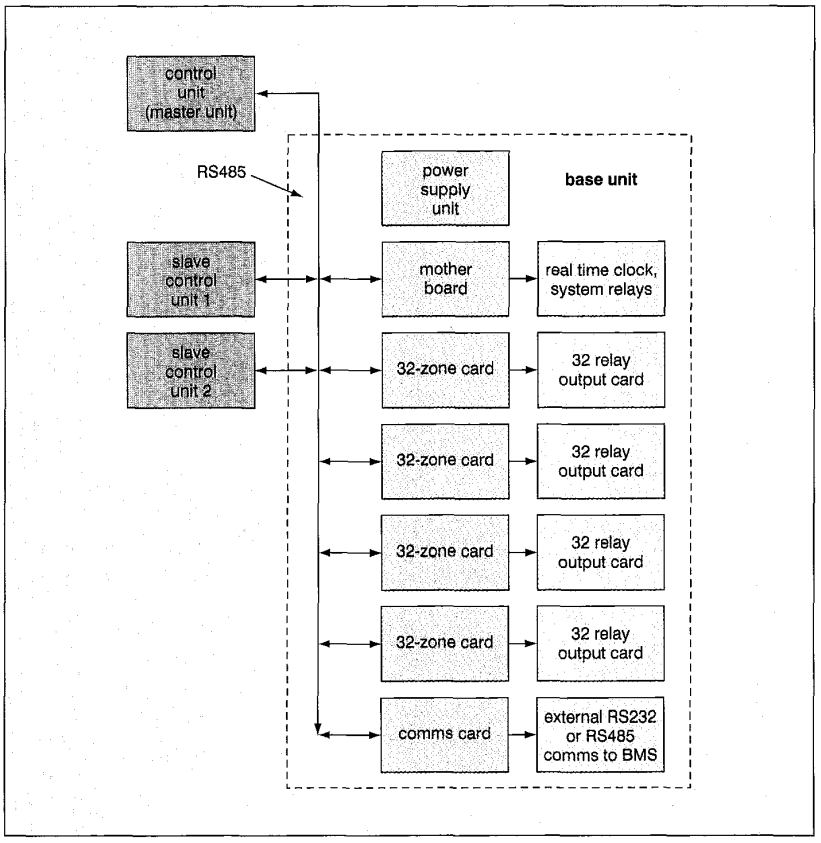

Fig. 6 Block diagram of Floodline 128 system (courtesy of Andel Ltd.)

down loaded from a laptop PC. Software in the PC allows the configuration data to be captured, edited and stored on disc. This simplifies the task of the installation engineer and enables Andel to maintain correct site details.

The control unit periodically acquires the zone voltages and calculates resistance values from each of the 32 zone cards. The status of each zone is then determined. This zone status is used to set or clear system and individual alarms as appropriate via additional control messages to the various elements in the system. Any change in zone status is recorded in the fault log. The control unit outputs are:

- a fault log
- a resistance log on a zone-by-zone basis for the last seven days
- visual and audible alarms for system faults via the motherboard
- individual zone alarms via a 32-zone card
- status information to site BMS via serial communications ports
- a user interface to acknowledge and clear alarm states.

The resistance log can be downloaded to the PC and with off-line software identify spurious alarms. Adjustment of leak detection thresholds to ensure satisfactory performance of the system can then be implemented. The off-line data analysis software displays the logged data on an individual zone basis for a 24-hour period. Each of the last seven days of data can be sequentially selected. Dampness in zones can be displayed to form a trend analysis for a site. This is especially useful in the identification of so called spurious alarms.

Examples that have been observed were an alarm going off in the early morning and then clearing. Detector cables are sensitive to small amounts of moisture and can dry out subsequent to the initial exposure. In this case it was possible to locate the spurious alarm occurring at 6:15 am at a particular location. On investigation of the site it was found that a cleaner at the end of her session was swilling the floor with water and some of this was seeping through the floor joints causing the leak alarm to sound. Other investigations have shown that condensation formed in an area of a concrete building in the evening when the sun had set.

The motherboard has four detection module slots with each module capable of accepting 32 zones. A communications module allows full status and alarm details to be transmitted in a range of protocols to building management systems or remote alarm facilities.

New leak detection techniques are also nearing

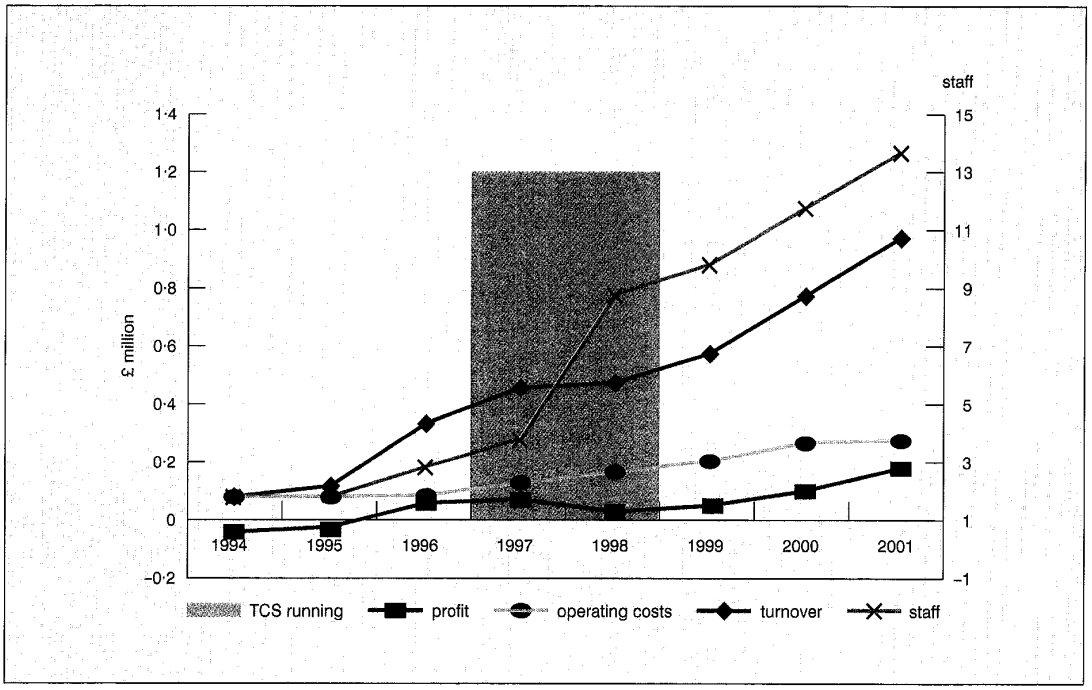

Fig. 7 Andel's performance 1994-2001

completion and the modular nature of the system allows these and future developments to be incorporated with ease.

Slave control units can also be added to the system to provide additional status displays in different locations within a building complex to meet the needs of the staff managing the building.

How has the company benefited from participation in the TCS Programme?

Before the TCS Programme Andel, with three staff, had no in-house electronic design capability. It was obliged to rely on outside technical design using subcontractors, which was expensive, provided little continuity, and specialist support was not always available when required. After the programme Andel recruited the TCS Associate to be the Technical and Production Manager, and he now makes a large and important contribution to the company's knowledge and capability. He has overall responsibility for design and production of the electronic systems, and is head of new product development.

The launch of the new Floodline 128 products developed under the TCS Programme has secured and strengthened the company's market position. It has opened markets barred at the start of the TCS Programme due to the inadequacies of the initial products.

The TCS Programme was the largest research and development activity undertaken by Andel and its impact has been significant.

The company has increased its staff levels, turnover and profit as a result of the TCS Programme and predicts that they will be maintained during the next three years. Andel has benefited from the introduction of new design techniques, particularly microcontrollers, to its existing and new products. Results for Andel are shown graphically in Fig. 7.

Conclusions

This TCS Programme was very beneficial to Andel Ltd., the TCS Associate and Bolton Institute. New products were developed and a long-term relationship has now been established between the parties.

The work described in this article was undertaken in a TCS Programme sponsored by the DTI. The TCS Programme won the prize for Engineering Excellence (sponsored by the Royal Academy of Engineering) at the TCS Awards 1999. The Floodline 128 leak detection system was a Millennium Product in 2000. In 2001 Andel Ltd. was awarded the Queen's Award for Enterprise (Innovation Category) for the work involved with the development and marketing of the Floodline 128 system.

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