Electrical Transducers by Mike Hopkins Msc

INTRODUCTION TO DIGITAL TRANSDUCERS

Conventional transducers convert a physical measurement into a useful electrical signal that can be displayed, recorded, transmitted and processed. Traditionally this signal is a dc current (or voltage) proportional to the physical quantity measured. In this form it has been a simple matter to pass the signal through remote indicators, recorders and other current registering devices using a pair of conductors. Where a large number of signals are transmitted multicore cables are often employed or a multiplexing system is used to combine the signals over a single transmission path. Multiplexed systems cut the cost of cabling and make it easier to route signals in a system.

Most of the more complex systems involve some sort of digital processing by computer or logic based devices. Such systems require the signals to be converted into a digitally encoded form by an analogue to digital (A to D) convertor. One of the most efficient ways of transferring this digital information is as groups of single sequential bits, a process known as a serial data link. Personal computers (PCs) and programmable logic controllers (PLC's) are invariably fitted with a serial input/output (I/O) port allowing them to communicate with external devices in this manner. The commonly used standard for this communication is known as RS232. The standard sets out the physical parameters of the link and the way that the information is conveyed in the form of words containing a fixed number of bits. The meaning of the words is not fixed by RS232 but by a separate protocol.

Serial data signals are easy to combine and hence to multiplex. The functions of multiplexing and A to D conversion can be profitably combined to yield a transducer that can talk directly into digital systems. With a suitable protocol a large number of such devices can share the same transmission link. There are definite advantages to such a system and they have become quite common at a network level where computers and PLCs are inter-linked and exchange data at fairly high rates. Despite the obvious advantages the same has not occurred at transducer level. Most designs still use conventional current signal transducers and external add-on A to D convertors. This reluctance to change is partly due to conservatism (similar to that, which greeted PLCs when they were first introduced) and to the confusion over a suitable protocol. A number of protocols have been developed for this purpose, some of which are proprietary and others, which are in the common domain. Potential users seem unwilling to commit themselves to protocols which tie them to a particular brand of equipment or which may prove to be non-standard in the future. Manufacturers have added to the confusion by energetically touting their own favoured systems so as to gain a market advantage.

Carrel and Carrel transducers presently support MODBUS, a popular established open protocol which is usable with many control products and systems. The company is aware of other more modern systems such as DeviceNet and Foundation Fieldbus. In due course transducers will be made available in these systems, as they become more popular.

MODBUS TRANSDUCERS

MODBUS is a digital data communication protocol developed by Gould Modicon for use in Modicon PLC systems. It is now an open system available to all users with Gould retaining limited proprietary rights. The protocol is widely used and the technical details of its operation are freely available. Many makes of PLC have MODBUS ports for communication with peripheral devices. The protocol is easily handled in software that is available from commercial vendors. Using MODBUS can save a considerable amount of cabling and interfacing costs. The MODBUS specification covers only the protocol so it is possible to use any physical medium of communication such as direct cable, modem, radio or optical means to transmit the messages. The most common form of communication used in practice is twisted pair cable employing the RS485 specification.

MODBUS is a master/slave system. One station, usually a PLC or computer, acts as the master controller and is the only station that can initiate communication. It sends a message to a particular slave unit under its control. If the message is a request for information then that unit replies with a message containing the requested information. This arrangement obviously suits a system where data gathering is fairly routine and there is not a large number of real time dependent alarm raising conditions.

A message to a slave contains the address, the command and some data related to the command.

The protocol allows individual slave units to be addressed by a unique identifying number in the range 1 to 247. In practice the physical transmission system may limit the number of stations. Many software systems accommodating MODBUS call the slave address a "node"; a term used in computer network practice.

There are 19 different commands in MODBUS, many of, which are irrelevant as they relate to PLC functions such as programming, logging and alarms. The functions most used are those relating to outputs or inputs either as the status of individual devices (on/off) or digital quantities (readings). Transducers use commands numbered 03 or 04 in the MODBUS code, which are requests for data register contents. These register contents are digital 16 bit integer figures (ie 0 to 65535 or -32768 to +32767) which are transmitted back to the master. Zero and full span inputs are equated to their respective register integer quantities. Linearity of conversion is assumed and the received values converted to the real quantities using the relevant conversion factors.
MODBUS protocol permits two different methods of encoding the message.

RTU (Remote Terminal Unit) mode breaks the message into byte (8 bit binary) sections with the first byte representing the address, the second byte the command and subsequent bytes the data.

The ASCII (American Standard Code for Information Interchange) mode sends the same message as a number of printable ASCII hexadecimal characters representing the elements of each section of the message. Each byte takes two 7bit ASCII characters to represent it. ASCII mode takes almost twice as long to transmit a message as the RTU mode. ASCII mode is useful for in-situ reading of messages on a terminal but is inefficient. Carrel and Carrel transducers use RTU mode and do not support ASCII mode.

The data component of a reading request consists of two 16-bit numbers. The unit receiving the request will have one or more 16-bit registers containing numerical information. The first two bytes of the request point to the location of the first register read whilst the second two bytes represent the number of to be read. The reply data consists of a string of one or more 16-bit register figures.

As a check on the veracity of the digital message two coded bytes are appended to the end of the message. This CRC (Cyclical Redundancy Check) gives a coded figure derived from the bits in the main part of the message. Doing this derivation in reverse checks if any of the digits have been corrupted in transmission. The normal practice is to ignore any messages presenting a CRC error. Most systems employing MODBUS tolerate a limited number of unsuccessful attempts to obtain a reading before raising an alarm. Although MODBUS protocol does allow for a byte-by-byte parity check, in practice this option is dropped, as the CRC test is more effective.

In the case where an uncorrupted message is received but the receiving unit is unable to act on it, an error message is indicated by inserting the most significant bit in the second byte of the reply (i.e. by adding 128 to the value of the command). The third byte of the reply contains a code number indicating the type of fault. Code 01 indicates that the command is not possible for that device; code 02 indicates that the data address is not possible whilst code 03 indicates a larger number of readings than is possible.

Carrel and Carrel transducers are capable of performing a loop back function. If the second byte contains the command function 08 then the transducer will return the message exactly as it was sent thus allowing a simple check to be made of the communication link.

RS485 is a specification covering a means of digital communication using a balanced twisted pair cable. Because input/output ports do not involve a common ground the common mode and interference resisting properties are superior to systems such as RS232. A converter (type LP-SSC) is available to convert RS232 ports to RS485 and to galvanically isolate the twisted pair from any sensitive circuits on the RS232 side. MODBUS transducers use a half-duplex system with only one twisted pair being used to transmit and receive on. The specified maximum cable length is 1200 metres. Up to 32 stations are permitted in parallel across the cable. The cable should be terminated in a resistance of 120 to 220 ohms at the remote end to avoid reflections. Long branches or stubs should be avoided. For short runs the twisted pair may not need to be screened. For long runs and harsh electrical environments screening is recommended. Carrel and Carrel transducers incorporate surge-suppressing devices between the conductors, the screen and ground to protect the units from damage due to electrical transients.

A full description of the MODBUS protocol is presented in the Gould Modicon publication Pl-MBUS-300 "Gould Modicon Modbus Protocol Reference Guide"

DETAILS OF Carrel & Carrel MODBUS TYPE TRANSDUCERS

A brief description of various MODBUS digital transducers is presented. Full technical details of these transducers appear in the Carrel Precision catalogue of LP series transducers and in other data sheets obtainable from Carrel and Carrel.

General description

The transducers reduce the measured parameters to a digital form that is available at the output as RS485 signals suitable for twisted pair cable transmission. The protocol used is MODBUS, RTU mode. The MODBUS address of the transducer is set using a binary weighted DIP switch. With most models a Baud rate of 9.6 kHz or 19.2 kHz can be selected. A reply delay of approximately 60ms can also be invoked to allow for the switching of computer ports from transmit to receive. The units react to MODBUS commands 03 or 04 (read registers) and return a 16-bit word equivalent in value to the measured value. The units also react to the 08 command (loop back), by sending the message back unchanged, as a check of the communication link. Illegal instructions are returned with standard MODBUS error messages.

Current	LP-ID	Converts a standard 1A or 5A ac current signal to the arithmetic mean value scaled to rms.
Voltage	LP-VD	Converts ac system voltages up to 500V to the arithmetic mean value scaled to rms.
Power	LP-1W1D	Watts in single phase system
	LP-1W3D	Watts in three phase balanced load with one CT
	LP-2W3D	Watts in three phase unbalanced load with two CT’s and no neutral (3ph-3w)
	LP-2.5W4D	Watts in three phase unbalanced load with three CT’s and a neutral (3ph-4w)
Reactive power	LP-1V1D	Vars in single phase system
	LP-1V3D	Vars in three phase balanced load with one CT
	LP-2V3D	Vars in three phase unbalanced load with two CT’s and no neutral (3ph-3w)
	LP-2.5V4D	Vars in three phase unbalanced load with three CT’s and a neutral (3ph-4w)
Energy	LP-1KW1M	KWhrs in single phase system
	LP-2KW2M	KWhrs in two phase system
Temperature	LP-TRD	PT100 resistance converted to temperature with linear correction
Multi-function	DT-MF2	Versatile microprocessor based unit capable of deriving a large variety of electrical readings, maximum demands and averages. Replaces a number of individual transducers and devices
Multiplexer	LP-MODMUX8	8 x dc inputs to MODBUS. Converts conventional transducers to MODBUS and incorporates a 24V dc power supply to energise loop powered transducers

SOME TYPICAL SYSTEMS USING DIGITAL TRANSDUCERS

Two examples are presented to illustrate how digital transducers can be used to provide information in a system whilst reducing costs.

EXAMPLE 1

A large shopping centre wishes to control their operating costs by limiting their maximum demand and by running their air conditioning plant at optimum settings. They would like to site their control room in their office, which is a cable distance of 200m from their incoming sub-station and 150m from their air conditioning plant.

Their engineers elect to transmit data from the sub-station and the plant to a computer in the control room. The computer will monitor the power levels and send control signals to the plant to keep it running at optimum efficiency and minimum load.

Besides a large number of on/off signals and indications it is decided to send the following analogue signals.

Incoming supply		3 x I, 3 x V, Watts, Vars = 8 channels	
Plant	Motors		
	Compressor	I, Watts, speed	
	Main fan	I, Watts, speed	
	Recirc. fan	I, Watts, speed	
	Cooling tower fan	I	
	Circulating pump I	= 11 channels	
	Temperatures	Inlet (dry bulb, wet bulb)	
		Outlet (dry bulb, wet bulb)	
		Cooling water (in, out)	
		Interior (two places)	= 8 channels

<u>CASE 1</u> <u>Using conventional transducers and multicore cables</u>

Transducers required (the most economical types for the work)	8 x LP-IS current transducers
	3 x LP-VS voltage transducers
	1 x LP-2.5W4 Watt transducer
	1 x LP-2.5V4 Var transducer
	3 x LP-1W3S Watt transducers
	8 x T-TRL Pt100 transducers
	Speed signals taken from drives
Cable requirements (minimum)	200m x 16 core screened (9mm diam)
	150m x 36 core screened (12mm diam)
Other equipment	Power supply 24V, 160mA dc (for T-TRLs)
	Junction box with >56 terminals
	Computer with 28 channel A/D convertor

Cable costs can be reduced by using only 50m of 16 core cable to reach the plant chamber and then transferring into a 150m section of 54 core cable which carries the plant signals as well. In practice this is not advisable as it would entail terminating into an additional set of terminals which would raise the cost. Also note that in practice one would use cables with more cores than are necessary so that some cores are available as spares. In practice one would also use two 16 channel A/D convertors.

<u>CASE 2</u> <u>Using individual digital transducers and twisted pair cable</u>

Transducers required (the most economical types for the work)	8 x LP-ID current transducers
	3 x LP-VD voltage transducers
	1 x LP-2.5W4D Watt transducer
	1 x LP-2.5V4D Var transducer

	3 x LP-1W3D Watt transducer
	8 x LP-TRD Pt100 transducers

The drives would be fitted with Modbus interfaces as well.

Cable requirements	200m twisted pair screened
Other equipment	RS485 to 232 convertor Computer with serial interface

24 addresses (nodes) are required for this system leaving a possible further 8 to be used for the three drives and the on/off functions. The most practical way to arrange the on/off functions is to pass them through a local PLC with a Modbus port. In this manner the PLCs can also be used for basic local control functions such as tripping, timing, starting sequences, level control and back-up operation. RS485 allows up to 32 stations therefore up 5 PLCs can be employed for this purpose in this system.

CASE 3 Conventional transducers with a digital multiplexer

Transducers required	8 x T-IL current transducers
(the most economical	3 x T-VL voltage transducers
types for the work)	1 x LP-2.5W4 Watt transducer
	1 x LP-2.5V4 Var transducer
	3 x LP-1W3 Watt transducer
	8 x T-TRL Pt100 transducers
	3 x LP-MUX8 multiplexers

The drives would be fitted with Modbus interfaces as well.

Cable requirements	200m twisted pair screened
Other equipment	RS485 to 232 convertor - Computer with serial interface

Only 3 addresses are taken up by the multiplexers, which also have built in power supplies for operating the loop-powered transducers. These loop circuits can also include local panel meters thus making the wiring of the front panel easier as this can be done in low current, low voltage wiring. The other signals would be arranged as in case 2. There would be many spare addresses available for other uses.

EXAMPLE 2

A hypothetical industrial complex has 24 measurement centres plus a master station arranged in 5 x 5 grid with each centre 50m from the next one and the master occupying the centre position. Cables are presumed to follow the most direct route from the point of measurement to the master station. Each measurement point has 8 analogue channels of current, voltage or temperature using loop powered transducers.

CASE 1 Conventional transducers and multicore cables

Transducers required	192 x loop powered type
Cable requirements	2343m of 16 core screened cable
Other equipment	24 x power supplies 24V, 160mA dc Termination panel with 384 terminals 12 x 16 channel A/D convertors 12 channel multiplexer and interface

The cable length is derived from a mathematical analysis of the direct paths. Cables are assumed to run in existing ducts.

CASE 2 Loop powered transducers with LP-MUX8 units

Transducers required	192 x loop powered type 24 x LP-MUX8 multiplexers
Cable requirements	1200m of twisted pair screened cable
Other equipment	RS485 to 232 convertor Serial port to computer

The conventional system requires almost double the length of more expensive cable and the equipment required at the master station is more complex. A system using LP-MUX8s would not need separate power supplies for the loop-powered transducers.