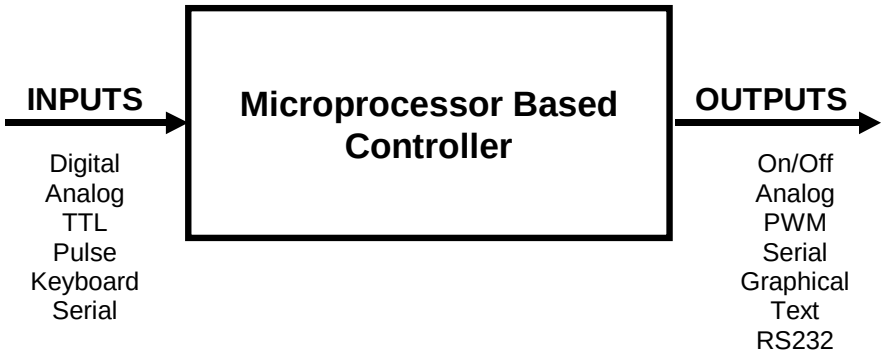
MICROPROCESSOR BASED CONTROLLERS



Abstract:

A controller is a system that reads various inputs and manipulates the data to produce appropriate outputs. Controllers can be used to monitor, limit, automate or enhance the operation of a machine. This paper describes the various aspects of Microprocessor Based Controllers. Also, a procedure to specify Microprocessor Based Controllers is given at the end.

Introduction:

Microprocessor Based Controllers (MBCs) have more power and flexibility than their analog counterparts could ever wish for. They are a marriage between hardware and software. Neither of which can function on their own.

Hardware:

The MBCs' hardware is the physical components that make up the system. The three main categories of hardware are Processor, Input and Output. Understanding the hardware is important when defining the scope of a controller. If the MBC doesn't have enough memory, certain data may not be able to be stored. If a machine state is not sensed, it cannot be considered by the program. Finally, if the controller does not have the appropriate output signal, a certain function may not be able to be controlled.

Processor

The hardware that is under the processor category include the microprocessor, memory, latches and so on. This part of the circuit does the calculations, stores the program and data, and directs the data flow. Generally, this part of the MBC can be assumed to be a block. The processor block can be assumed to be able to handle the needs of the MBC. However, in order to help the reader understand this part of the MBC, the following are some definitions of common processor components.

CPU	The Central Processing Unit is the heart of the system. It is the chip that does all of the calculations.
RAM	Random Access Memory is fast memory that is used while the MBC is running. When the power is turned off, any data stored in RAM is lost.
Battery Backed RAM	This is RAM that has a battery built in it so that the memory is not erased when the system is powered down. (nonvolatile)
ROM	Read Only Memory is permanent memory, which cannot be written to. ROM generally is used to store the program or other predetermined information (i.e. Lookup Tables).
EPROM	Erasable, Programmable Read Only Memory is a ROM chip that can be programmed. EPROM can be erased in a special eraser, letting the chip be reprogrammed again.
EEPROM	Electrically Erasable, Programmable Read Only Memory is a ROM chip that can be programmed. EEPROM can be erased electrically. This makes EEPROM semi-permanent memory. This is good for storing calibration and other operating data. The CPU can erase and write to the EEPROM while it controls the machine.

Inputs

Input hardware is where the MBC gets information from the world. The input is the MBC's eyes to the world. The information can come from the operator or the machine being controlled. There are three basic types of inputs including Digital, Analog, and Data.

Digital

Digital inputs are signals that are either on or off. This binary data is commonly used in conjunction with the following sensors.

Operator Switches	Toggle Switches, Push Buttons and other switches that are controlled by the operator indicate commands or states.
Machine Switches	Limit Switches indicate machine positions.
Speed Pickups	Pulse inputs from magnetic pickups can be put into a Schmidt trigger (filter) and then into a digital input. Engine RPM or other speed information can be read by the MBC.

Analog

Analog inputs are signals that can have a value anywhere within some range (typically 0 - 10VDC). Sensors that create a proportional signal are used with analog inputs.

Potentiometers	Potentiometers controlled by the operator can indicate speed, or amount of flow to the MBC. A potentiometer operated by a machine joint can indicate boom position or swash-plate position.
Levers	Proportional levers that are used for functions that use metered control (feathering) use one analog input per axis or function.
Angle Sensors	Gravimetric angle sensors produce an analog signal and therefore require an analog input per signal.

Length Sensors - Cable reel length sensors use potentiometers to produce an analog signal for an analog input. Length sensors can be used to indicate boom length or other machine geometry.

Data

Data inputs are specialized Digital inputs. These include inputs from Keyboards, serial/parallel communication (i.e. from another computer). Telemetry used with remote controls come in as serial data.

Outputs

The output is the key to the MBC. Without output, the MBC just sits there. In order to get the desired control, the appropriate outputs are needed. There are three basic types of outputs, including On/Off, Proportional and Data.

On/Off

On/Off outputs can have high or low currents, depending on the load. Typical uses for On/Off outputs are listed below.

Solenoids	Solenoids are either open or closed and can be used to direct hydraulic flow.
Lights and Buzzers	Indicator lights, buzzers, horns and other similar devices can be activated with On/Off outputs.
Relays	If high currents need to be switched, or the output needs to be isolated, On/Off outputs can activate relays.

Proportional

Proportional outputs are used when a function needs to be controlled continuously from off to on. An example is a flow control valve. The valve can be closed, open or anywhere in-between. The main types of proportional outputs are Analog and Pulse Width Modulated (PWM).

Analog outputs are a DC voltage that varies typically from 0 to 5 volts. These outputs can be used to supply power to valves, levers or anything else that needs an analog signal.

PWM outputs are signals typically used to control valves directly. The PWM signal is either on or off (supply or ground), but the average voltage varies proportionally from 0 to supply. PWM signals are more efficient for supplying high power signals.

Data

Data outputs are specialized Digital outputs. These include signals to text displays, graphical displays, memory, and serial/parallel communication. Telemetry used with remote controls can be sent as serial data.

Software:

Once the hardware is selected, it is important to consider the software. The software controls the data flow, and makes the hardware run. There are four basic types of programs that can be used with MBCs. These are Interpreter, Monitor, Limiting and Automation. An actual program may combine any or all of these program types.

Interpreter	A program that reads in certain inputs and activates corresponding outputs is acting like an interpreter. For example a lever creates an analog input, causing the MBC to output a PWM output to control a valve.
Monitor	An MBC set up to monitor a system will measure various inputs which correspond to machine conditions of interest. The MBC can extract certain information. This information can be stored in memory, displayed or transferred to another computer. This can be very useful for diagnostics. For example, the MBC can have Oil Temperature and Oil Pressure as analog inputs. The MBC can calculate averages and can keep track of extremes. This information can be stored in memory to be used by service personnel.
Limiting	As a special case of a monitor program, a limiting program can keep a monitored machine state within a specified region. One example is a Load Moment System on a crane. If the crane is becoming unstable (overloaded), the MBC can activate warnings and can inhibit certain “unsafe” functions. Another example of a limiting program is one that cuts the hydraulic functions when the engine speed drops too low.
Automation	If the machine being controlled repeats the same identical routine over and over, it may be advantageous to eliminate the operator as much as possible. The operator could just press a START button and let the program do the rest. Garbage trucks are excellent examples of a machine that repeats the same procedure time after time. One cylinder may be activated until its corresponding limit switch trips. Then another cylinder is operated until its limit switches. This is repeated until the routine is completed.

Specifying a Microprocessor Based Controller:

When buying or ordering an MBC the following is a step by step procedure to simplify the process.

1. Specify Digital Inputs - List the Digital inputs and their voltage ranges.

2. Specify Analog Inputs - List the Analog inputs and their voltage swings.

3. Specify Data Inputs - List any Data inputs.

4. Specify On/Off Outputs - List On/Off outputs and their current ratings.

5. Specify Proportional Outputs - List Proportional outputs and their current ratings.

6. Specify Data Outputs - List the Data outputs.

7. Describe the desired MBC operation. Describe any monitoring, limiting or automation to be done by the MBC.

Practical Example

In order to illustrate how to specify an MBC, the following is a sample specification for a fire ladder truck. Imagine a ladder truck with local controls at the base of the ladder and another set of controls at the end of the ladder, linked to the MBC by radio.

1. Specifying Digital Inputs:

No.	Description	Voltage Swing
1	Horn - Momentary Push Button	0, 12VDC
2	Lights - SPST Toggle Switch	0, 12VDC
3	Engine SPDT Momentary Toggle Switch (Start/Run/Stop)	0, 12VDC
4	Outrigger Boom SPDT Momentary Toggle Switch (Extend/Retract)	0, 12VDC
5	Outrigger SPDT Momentary Toggle Switch (Up/Down)	0, 12VDC
6	Safety Override - SPST Toggle Switch with Slap Guard.	0, 12VDC

2. Specifying Analog Inputs:

No.	Description	Voltage Swing
1	Ladder Up/Down Lever	6 ± 3VDC
2	Ladder Extend/Retract Lever	6 ± 3VDC
3	Ladder Rotate CW/CCW	6 ± 3VDC
4	Pressure Transducer - Base of Main Cylinder	0 - 10 mVDC
5	Pressure Transducer - Rod of Main Cylinder	0 - 10 mVDC
6	Cable Reel - Length Sensor	1 - 4 VDC
7	Angle Sensor	0 - 10 mVDC

3. Specifying Data Inputs:

No.	Description
1	Radio Remote input from Ladder Basket. Controls are duplicates of Local controls.

4. Specifying On/Off Outputs:

No.	Description	Current Rating
1	Horn	500mA
2	Lights	100mA
3	Engine Start	4A
4	Engine Kill	2A
5	Outrigger Boom Extend	2A
6	Outrigger Boom Retract	2A
7	Outrigger Down	2A
8	Outrigger Up	2A
9	Warning Light	0.5A
10	Buzzer	0.5A

5. Specifying Proportional Outputs:

No.	Description	Voltage Swing and Current Rating
1	Ladder Up (PWM)	2A @ 12V
2	Ladder Down (PWM)	2A @ 12V
3	Ladder Extend (PWM)	2A @ 12V
4	Ladder Retract (PWM)	2A @ 12V
5	Ladder Rotate CW (PWM)	2A @ 12V
6	Ladder Rotate CCW (PWM)	2A @ 12V

6. Specifying Data Outputs:

No.	Description
1	4x20 Text Display

7. Describing the desired MBC operation:

- Measure ladder load using the pressure transducers, the length sensor and the angle sensor. When the load exceeds the stored Load Chart, the MBC stops the Ladder Down and Ladder Extend functions. The MBC also turns on the Warning light and Buzzer. If the Safety Override Switch is activated, the Ladder Down and Ladder Extend functions are allowed.

- The Local station has priority over the remote control. If the Local station controls are activated, the radio remote signals are ignored for ten seconds. In other words, the local station needs to be idle for ten seconds before the radio signal is considered.

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