PIDChip120

Programmable Universal PID Controller

Description

PID control is the most efficient and universal form of control for common electrical and electromechanical systems. As a control technique, its reliability and ease of use has been proven in many industrial and field applications. The PIDChip series controllers are low cost single-chip PID control solutions designed to accommodate almost any application with unparalleled ease of use and fast integration into any system.

Features:

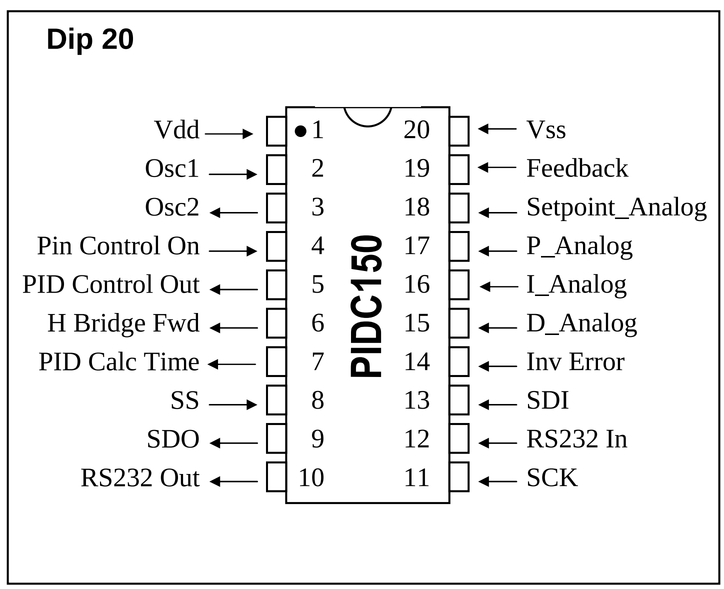
- Low external part count
- 10-bit control processing
- High speed ultrasonic PWM/Analog output with H-bridge drivers
- Stand-alone operation
- RS232 shell control and logging option
- Analog input parameter control option
- Serial peripheral interface (SPI) control option (PIDC150 only)
- Built-in flash memory for parameter and set point storage
- Sample/update rate 1.22k to 0.037 Hz
- Control processes with response times from 10 ms to 10 minutes
- Low Power CMOS design

The PIDC series controllers are 20 pin integrated circuits that need only an external 20MHz crystal to operate. They are built with ease-of-use and flexibility in mind, allowing multiple configuration and tuning methods. They can be configured with a simple RS232 interface and terminal window, such as Hyperterminal, or the control parameters and setpoint may be entered through four analog inputs and can be changed during operation, allowing on-the-fly experimentation and process adjustment. For the PIDC150, parameters and the set point may be entered serially through the 3-wire SPI interface. For all models, the parameters and setpoint are stored in nonvolatile flash memory, and re-loaded automatically upon startup if power is removed.

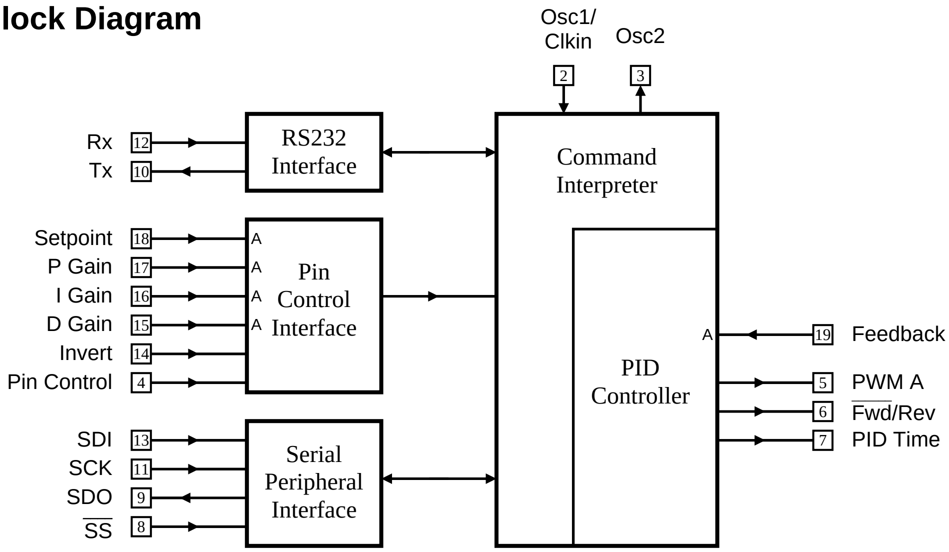
Applications

- Temperature control
- Peltier/thermoelectric control
- Motor control
- Flow control
- Inverted pendulum control
- OEM integration
- Classroom/hobbyist demonstration

Pin Diagram



Block Diagram



"A" Denotes analog input; all others are TTL.

Pin Descriptions

V_{DD} (Pin 1)

Positive Supply Pin. The Voltage of all other inputs should be no greater than the Voltage on this pin. V_{DD} also serves as the analog input and digital level reference.

V_{SS} (Pin 20)

Vss is the ground reference for power and I/O pins - analog and digital. No input should go below V_{SS}.

Osc1 (Pin 2)

Oscillator or crystal external clock input. A 20MHz crystal or a 20MHz clock may be connected to this pin.

Osc2 (Pin 3)

Crystal driving output pin. Connects to crystal or resonator. Unconnected if external clock generator is used.

Pin Control (Pin 4)

Used to enable Analog pin control of parameters using the pin control interface. A high level input sets pin control on, a low level input sets pin control off. A high to low transition will cause the input values at the pin control interface to be stored to EEPROM.

Setpoint (Pin 18)

Analog input from V_{DD} to V_{SS} that is the desired control set point during pincontrol operation. Unused if pincontrol is off.

P Gain (Pin 17)

Analog input from V_{DD} to V_{SS} that is the desired control proportional gain during pincontrol operation. Unused if pincontrol is off.

I Gain (Pin 16)

Analog input from V_{DD} to V_{SS} that is the desired control integral gain during pincontrol operation. Unused if pincontrol is off.

D Gain (Pin 15)

Analog input from V_{DD} to V_{SS} that is the desired control differential gain during pincontrol operation. Unused if pincontrol is off.

Rx (Pin 12)

RS232 receive pin. Used if RS232 terminal control is desired. Receives characters from computer.

Tx (Pin 10)
RS232 transmit pin. Used if RS232 terminal control is desired. Transmits characters to computer.

SDI (Pin 13)
Serial data input pin. Used if SDI parameter control is desired. Useful for microprocessor control.

SDO (Pin 9)
Serial data output pin. Used if SDI parameter control is desired.

SCK (Pin 11)
Serial data clock pin. Used if SDI parameter control is desired. Bidirectional serial clock for incoming and outgoing data.

$\overline{\text{SS}}$ (Pin 13)
Serial select pin. Used if SDI parameter control is desired. Typically high, this pin is set low by a microprocessor to activate data transfer to and from the SPI.

Feedback (Pin 19)
Analog feedback of control parameter. Controller attempts to make this equal to the programmed set point by varying PWM A and B. Input voltage should be between V_{DD} and V_{SS}.

PWM A (Pin 5)
Pulse width modulated output A. May be used alone or with PWM B for an H-bridge inverting control.

$\overline{\text{Fwd}}$/Rev (Pin 6)
Indicator pin for when H-bridge drive is in forward or reverse direction. May be used to shut off drive during reverse overshoot for nonreversible process control such as heating.

PID Calc Time (Pin 7)
Indicator pin outputs high when the feedback sample is taken and during the PID calculation loop.

Ordering Information: These integrated circuits are available in any of these packages: DIP, SOIC, SSOP.

Absolute Maximum Ratings (*)

Ambient temperature under bias...-40° to +125°C
Storage temperature .... -65°C to +150°C
Voltage on VDD with respect to VSS .... -0.3V to +6.5V
Voltage on all pins with respect to VSS .... -0.3V to (VDD + 0.3V)
Total power dissipation .... 800 mW
Maximum current out of VSS pin .... 300 mA
Maximum current into VDD pin .... 250 mA
Input clamp current, IIK (VI < 0 or VI > ....± 20 mA
Output clamp current, IOK (Vo < 0 or Vo ....± 20 mA
Maximum output current sunk by any I/O .... 25 mA
Maximum output current sourced by any I/O pin .... 25 mA
Maximum current sunk by all data pins (combined) .... 200 mA
Maximum current sourced by all data pins (combined).. 200 mA

* NOTICE: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Electrical Characteristics

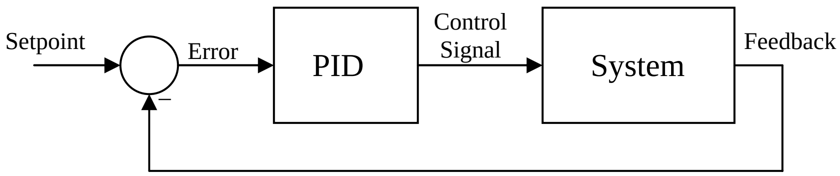
Characteristic	Minimum	Typical	Maximum	Units	Conditions
Supply Voltage (V_{DD})	4.5	5.0	5.5	V	
V_{DD} Rise Rate to ensure internal Power-on Reset	0.05	-	-	V/ms	
Supply Current (I_{DD})	-	2.8	3.35	mA	See note 1
Input Low Voltage Osc1	V_{SS} V_{SS}	- -	0.8 0.3 V_{DD}	V	$4.5<V_{DD}<5.5$V
Input High Voltage Osc1	2.0 0.7 V_{DD}	- -	V_{DD} V_{DD}	V	$4.5<V_{DD}<5.5$V
Output Low Voltage	-	-	0.6	V	See note 2
Output High Voltage	V_{DD} - 0.7	-	-	V	See note 3
Data Memory Endurance	100K	1M	-	E/W	$-40^{o}C < T_A < +85^{o}C$
RS232 baud rate	-	57600	-	Baud	See note 4

Note

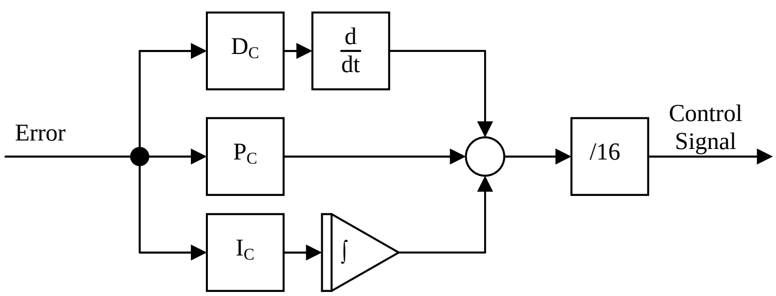
1. Device only. Does not include pin currents.
2. IOL = 8.5 mA, VDD = 4.5V (Ind.)
3. IOH = -3.0 mA, VDD = 4.5V (Ind.)
4. With a 20 MHz crystal or clock source. Typical 8 bits, no flow control, 1 stop bit (8N1)

Overview

The Proportional Integral Differential control method is a simple, robust algorithm that is able to drive a system to a set point as fast as possible with as little overshoot as necessary. The algorithm can also accommodate perturbances in the system fairly well, and adjust the control output to re-zero the error (difference between setpoint and feedback).



The PID controller operates by calculating an error value based on the difference between the setpoint and the feedback signal. It responds faster and more accurately than conventional ‘fuzzy logic’ controllers by calculating a response based on the current error (proportional term), the past error (integral term), and the rate of the error change (integral term). The proportional term alone adds a difference offset to the control signal based on the error term, the integral term allows the controller to reach a steady state nonzero output, and the differential term decreases the control signal based on how fast the setpoint is being approached, preventing overshoot of the setpoint.



There are four main control parameters for tuning this digital PID system: the Proportional gain, the Integral gain, the Derivative gain, and the update speed.

Update Speed

The update speed is the frequency that the PID loop samples the feedback and calculates a new control signal. The update speed is of primary importance, as it acts as a scaling factor for the Integral and Differential gain. The faster the update speed, the higher the integral gain and the lower the equivalent differential gain of the system. The update speed should be set to approximately 10 times the fastest response time of the system. The response time of a system is the time it takes the output of a system to reach 63% of its final steady state value in response to a step change in input. If you are tuning a system and observe that the integral gain must be near its minimum and the Differential gain near its maximum, it is likely that your update speed is set too high. Likewise, if the integral gain must be near its maximum and the differential gain near its minimum, the update delay (1/UpdateSpeed) needs to be decreased.

Proportional Gain

The proportional term gives a system control signal proportional to the error. Using only proportional control results in steady state error in most cases or error oscillations above and below the setpoint in the case where the proportional gain is too high. The proportional gain should be set to approximately 60% of the gain that causes oscillations with P and I gains at zero.

Integral Gain

The integral term of a PID controller sums the previous input errors of the system. Summing continues until the setpoint is reached or surpassed at which point the error becomes zero or negative, freezing or decreasing the integral term. The integral term may reach steady state at a negative value as well, depending on the process being controlled. Using only an integral term results in a slow and continuously oscillating system. The integral gain should be set so that the system reaches equilibrium in an acceptable time, but low enough that the setpoint is not overshot. The integral term should be balanced with the derivative term.

Derivative Gain

The derivative term adds or subtracts from the control term based on the rate of change toward or away from the setpoint. As the error term decreases, the derivative function calculates the rate of decrease and adjusts the control output accordingly. For example, lets say the setpoint is increased by 30 and the system begins to approach 30 faster and faster as the integral term increases. The D term will act in anticipation of reaching the setpoint and decrease the control output so that the setpoint is not overshot on the approach. Instead, the D gain should be set so that the D term balances the integral and proportional terms so that when the setpoint is reached the integrator will be at its steady state value, and the proportional term and derivative term will become zero. If the process is approaching the setpoint too slowly, or backing off before reaching it, the D gain may be too high and/or the I gain too low. Conversely if the system overshoots the setpoint, the D gain may be too low and/or the I gain too high.

Interface Options

The PIDChip Is designed to be as flexible and easy to use as possible. There are three input methods for entering the setpoint and the P, I, and D gains and Invert setting to the chip: RS232 terminal, external pin control, and SPI (150 only). The RS232 command mode emulates a command shell and is a simple way of interfacing to the chip and adjusting parameters on the fly and reading back error margins. External pin control may be used without any other computing hardware to set the device. Simple potentiometers and switches can entirely program the settings, with the exception of the update speed. The SPI is a high speed interface designed to be used in conjunction with a microprocessor controller for minimum overhead. It is able to control every aspect of operation, as can the RS232 interface.

The PIDChip uses 10 bit (0 to 1024 decimal and 0 to 3FF hex) analog to digital converters for acquiring the setpoint when using pincontrol and for acquiring the feedback value. The P,I,and D gains are internal 8-bit values (0 to 256 decimal or 0 to FF hex) and are acquired as such from the pincontrol inputs if desired. These parameters may also be entered in hex using the RS232 serial shell, or serially using the SPI port. The update speed can be changed by adjusting the loopdelay parameter using RS232 or the SPI port. Once the settings have been entered, they may be stored to the device’s internal EEPROM. Upon boot-up, the device loads the control parameters and setpoint into memory from the EEPROM and begins control immediately. Once the parameters and setpoint are stored, no other external communications is necessary for the device to operate and achieve equilibrium automatically. If desired, the setpoint or any parameters may be changed during operation via any of the three input methods.

PinControl Interface:

Pincontrol is turned on when the PinControlOn pin is brought high. When active, the three 8-bit PID gain values P,I,and D are set internally by sampling the voltage at the P_Analog,I_Analog,and D_Analog inputs. The value is set following the formula gain=V_x*256/V_{DD}. For example, if V_{DD}=5V and the input at P_Analog is 1V, the P gain will be set to 51, or 33h in hex. SetPoint is sampled with 10-bit precision, so the setpoint formula is setpoint=$V_{setpoint}$*1024/V_{DD}. Both the SetPoint and the process feedback inputs are sampled at 10 bits and are measured with respect to VDD, so small changes in supply voltage will not have a significant effect on the response of the system. The Inv Error pin is a digital input that is used to toggle the sign of the PID error signal. It can be used to invert the drive direction given a difference in setpoint and feedback signals. For example, if the digitized feedback and setpoint signals are 0x100 and 0x108, respectively, the error is 8, which would result in an increased PWM drive. If the process is such that a decreased drive is needed (such as a heating process where a negative temperature coefficient (NTC) thermistor is used), then the Inv can be set and the process control error will be inverted. Inv is implemented to decrease the need for external signal conditioning components. The PinControl values are sampled and updated at the end of every PID cycle.

Setting the Pincontrol values to EEPROM

The PinControl values are stored to EEPROM whenever the PinControl_On pin is brought low. Once stored, they will remain in memory in the PID control system during operation, and will be loaded from EEPROM if power is removed and restored. If PinControl_On is high when power is restored, the PID and Invert values will be again read from the pins, and the EEPROM values ignored.

RS232 Interface

The PIDC120 and 150 may be interactively controlled using an RS232 serial port from a computer set to 57600 baud, 8 data bits, 1 stop bit, and no parity (8-N-1). When the PIDC is powered on, the current device settings are displayed in your terminal, and a command prompt is printed for command entry. Setting new values using SetPID, SetPoint, and PIDSpeed causes the EEPROM to be updated to the new value immediately.

```
Booting...

LoopDelay = 09
PinControl is Off.
P = 10 I = 05 D = 60 Invert is On.
Setpoint = 110

Welcome to the PID Shell.

PID>
```

Example boot-up display and prompt.

RS232 Command Table

Command	Usage	Description
ReadPID	ReadPID	Displays the P,I,and D gains in hex
SetPID	SetPID P|I|D|^ XX	Sets the P, I, or D gains in hex
SetPoint	PetPoint [XXX]	Sets or displays the process setpoint in hex
PinControl	PinControl [On|Off]	Displays current status or turns PinControl on or off
DispError	DispError	Toggles continuous display of process error
LoopDelay	LoopDelay [XX]	Displays or sets the PID loop speed
?	?	Displays command set

ReadPID
This command will display the P, I, and D gain values in hex. Along with that, it will display whether Invert Error is on or off.

SetPID
This command is used to set the P, I, or D gains or to change the Invert Error status. Entry format is SetPID, then a space, then either P, I, D, or ^ (invert), then a space, then a two-digit hexadecimal value. For InvertError, 00 will turn invert off and a nonzero number will turn it on. Hexadecimal digits must be from 00 to FF. The parameter value in EEPROM is immediately updated when a new value is entered.

SetPoint
The SetPoint command is used to read or set the process setpoint. SetPoint by itself will display the setpoint, and SetPoint followed by a 3-digit Hex value will set that value as the new setpoint. As a 10-bit value, SetPoint is contstrained to be between 000 and 3FF. The setpoint in EEPROM is immediately updated when a new setpoint is entered.

PinControl
The PinControl command allows the user to turn on or off pincontrol. When picontrol is off, the chip gets the setpoint and process gains from the EEPROM, and when it is on, the setpoint and process gains are read from the analog input pins of the chip.

DispError
This command toggles the process error display on and off. The process error is the difference between the setpoint and the feedback, in hex. Instead of the normal prompt, you will get the process error prompt that continually updates.

Normal Prompt: PID>
DispError Prompt with an error of negative 3Bh : -3B>

LoopDelay
The LoopDelay command displays or sets the speed of the PID loop. When LoopDelay is followed by a two-digit hex value, the corresponding delay will be set, otherwise, the current delay will be displayed. LoopDelay values can range from 00 to 0F. Following is a chart of the loop delays and sample speeds available. At each increment

of loopdelay, the sampling delay is doubled. Although every process is different, a rule of thumb is that the sample and update rate of the digital PID controller should be 6-14 times the speed of the fastest time constant of the process. These times are shown in the chart.

Table 3: LoopDelay values and their timing impact.

Approximate Process Response Time	LoopDelay Value	PID Sample Frequency
8.19 mS	00	1220.7 Hz
16.4 mS	01	610.4 Hz
32.8 mS	02	305.2 Hz
. . .	. . .	. . .
67 Sec	0D	0.149 Hz
134 Sec	0E	0.0745 Hz
268 Sec	0F	0.0372 Hz

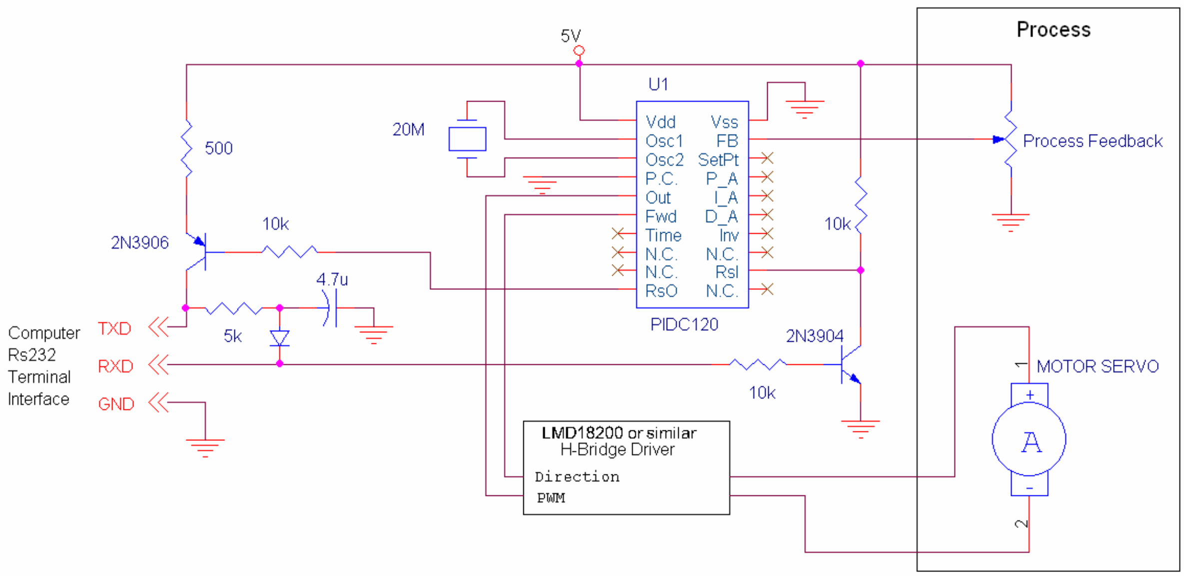
Note that Rs232 DispError is disabled for sample speeds above 152 Hz.

‘?’

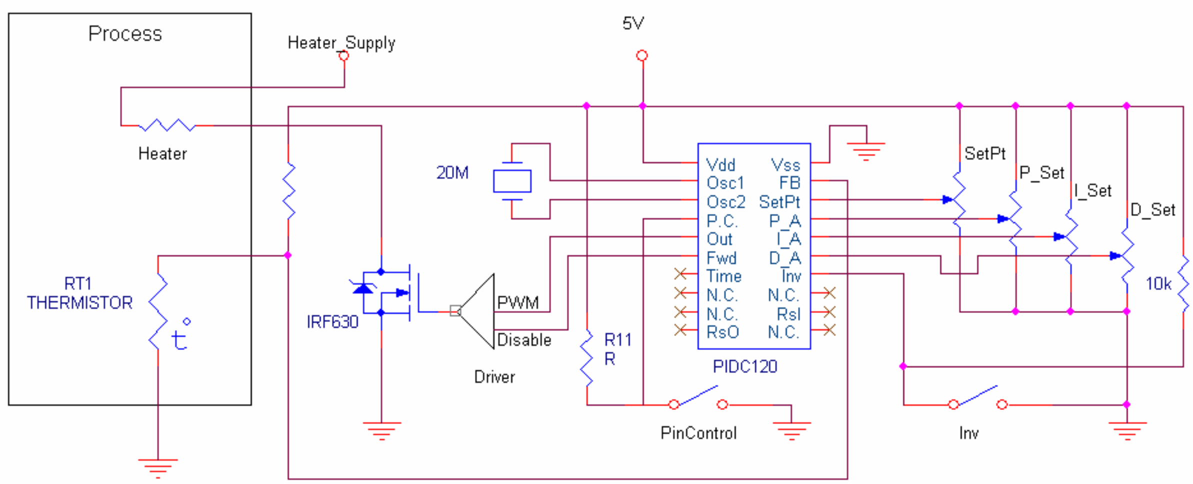
Entering ‘?’ will list the available commands.

Example Circuits:

Example circuit using H-bridge motor control and Rs232 interface:



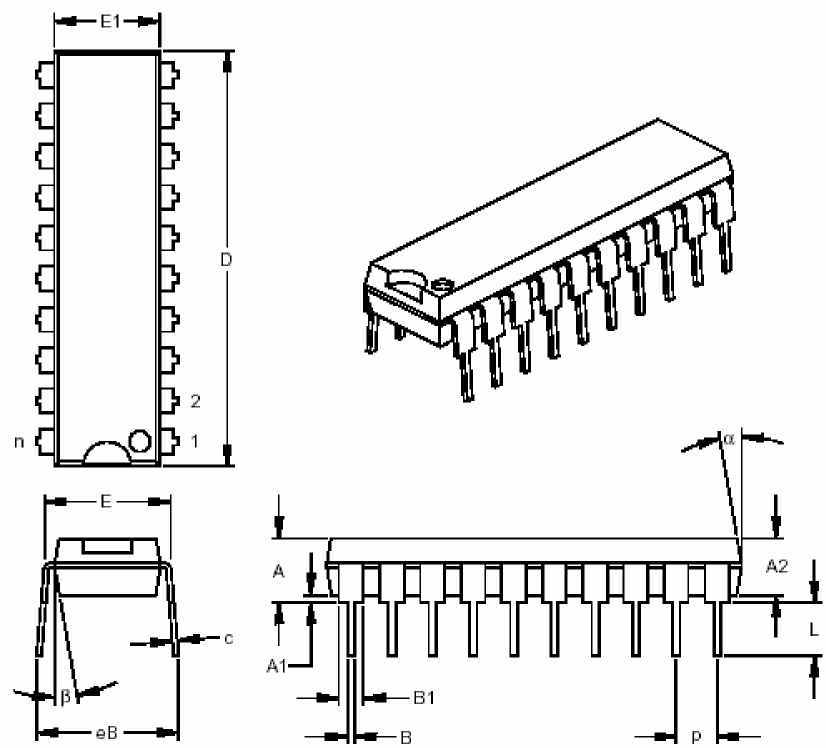
Example circuit using simple PWM heater and PinControl interface:



Notes:

Packaging

20-Lead Plastic Dual In-line (P) – 300 mil Body (PDIP)



	Units	INCHES*			MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		20			20	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.295	.310	.325	7.49	7.87	8.26
Molded Package Width	E1	.240	.250	.260	6.10	6.35	6.60
Overall Length	D	1.025	1.033	1.040	26.04	26.24	26.42
Tip to Seating Plane	L	.120	.130	.140	3.05	3.30	3.56
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.055	.060	.065	1.40	1.52	1.65
Lower Lead Width	B	.014	.018	.022	0.36	0.46	0.56
Overall Row Spacing §	eB	.310	.370	.430	7.87	9.40	10.92
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

* Controlling Parameter

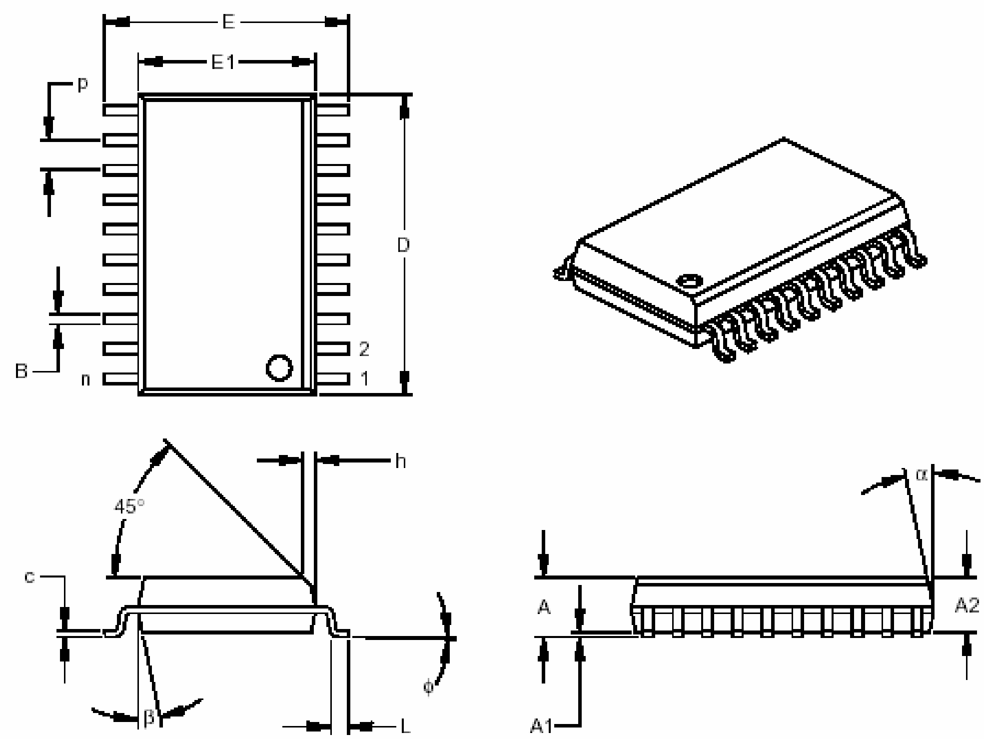
§ Significant Characteristic

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MS-001

20-Lead Plastic Small Outline (SO) – Wide, 300 mil Body (SOIC)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		20			20	
Pitch	p		.050			1.27	
Overall Height	A	.093	.099	.104	2.36	2.50	2.64
Molded Package Thickness	A2	.088	.091	.094	2.24	2.31	2.39
Standoff §	A1	.004	.008	.012	0.10	0.20	0.30
Overall Width	E	.394	.407	.420	10.01	10.34	10.67
Molded Package Width	E1	.291	.295	.299	7.39	7.49	7.59
Overall Length	D	.496	.504	.512	12.60	12.80	13.00
Chamfer Distance	h	.010	.020	.029	0.25	0.50	0.74
Foot Length	L	.016	.033	.050	0.41	0.84	1.27
Foot Angle	φ	0	4	8	0	4	8
Lead Thickness	c	.009	.011	.013	0.23	0.28	0.33
Lead Width	B	.014	.017	.020	0.36	0.42	0.51
Mold Draft Angle Top	α	0	12	15	0	12	15
Mold Draft Angle Bottom	β	0	12	15	0	12	15

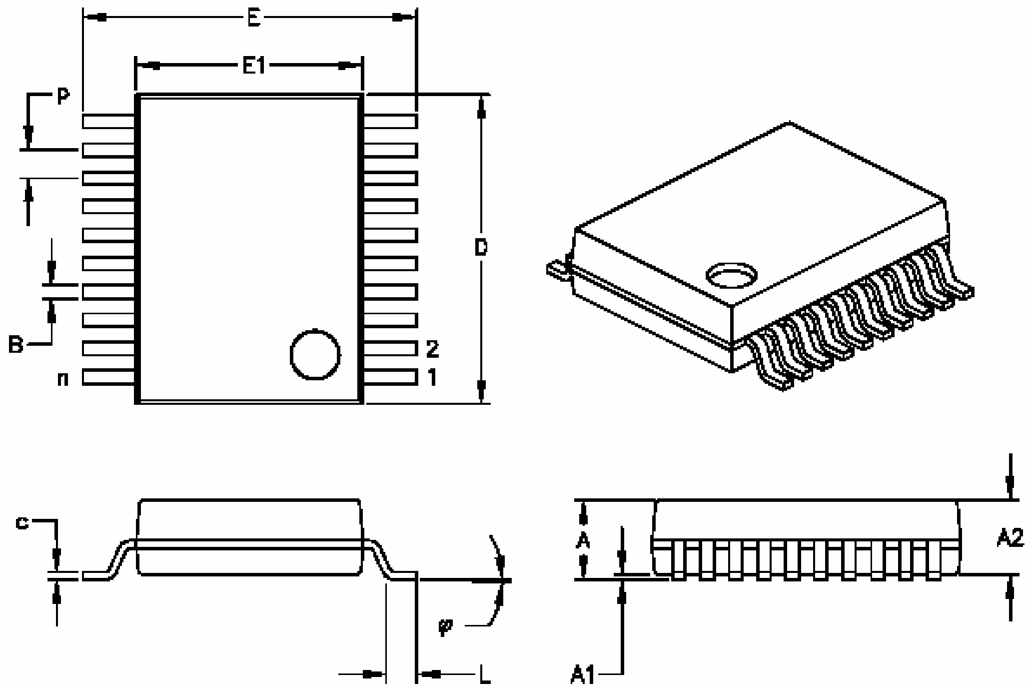
* Controlling Parameter
§ Significant Characteristic

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MS-013

20-Lead Plastic Shrink Small Outline (SS) – 209 mil Body, 5.30 mm (SSOP)



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		20			20	
Pitch	p		.026			0.65	
Overall Height	A	–	–	.079	–	–	2.00
Molded Package Thickness	A2	.065	.069	.073	1.65	1.75	1.85
Standoff	A1	.002	–	–	0.05	–	–
Overall Width	E	.291	.307	.323	7.40	7.80	8.20
Molded Package Width	E1	.201	.207	.212	5.11	5.25	5.38
Overall Length	D	.272	.283	.295	6.90	7.20	7.50
Foot Length	L	.022	.030	.037	0.55	0.75	0.95
Lead Thickness	c	.004	–	.010	0.09	–	0.25
Foot Angle	φ	0°	4°	8°	0°	4°	8°
Lead Width	B	.009	–	.015	0.22	–	0.38

*Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO–150