DIGITAL CONTROL *Without Programming*

by David Caldwell

A dedicated digital controller with intuitive settings makes it quick and easy to close a loop around a power supply, heater, motor, lamp, or other device.

Closed-Loop Challenges

Closed-loop controllers make automatic adjustments to maintain constant output despite varying conditions. Examples include supply voltage, fluid temperature, motor speed, and light intensity. These parameters would shift over time and load without consistent correction.

Microcontrollers executing firmware are replacing op-amps with feedback networks that used to perform closed-loop control. These digital implementations are versatile but time-consuming to program and control demands often exceed processor resources. Considerable expertise is required to properly design a system to avoid oscillations or sluggish responses. We naturally observe events in the time-domain while control analysis is typically done in the frequency-domain, which can be complex and confusing.

One solution to these challenges is an automated closed-loop controller configured by intuitive time-domain settings. CLOZD™ is a control chip developed by Flextek Electronics that is versatile and easy to use. Just select the desired timing configuration through pin settings and quickly close a loop around a power supply, motor drive, lamp, heater, fan, Peltier, valve, actuator, or amplifier.

Controller drive is automatically adjusted until the measured sensor signal matches the desired command, as shown in Figure 1. The Digital-Signal-Processing (DSP) algorithms within the CLZD010 control chip compare the feedback sensor signal and the analog setpoint command to determine appropriate Pulse-Width-Modulator (PWM) drive for the plant. Typical plants include power, thermal, motion, lighting, and flow applications.

Figure 1. CLOZD loop controller system application.

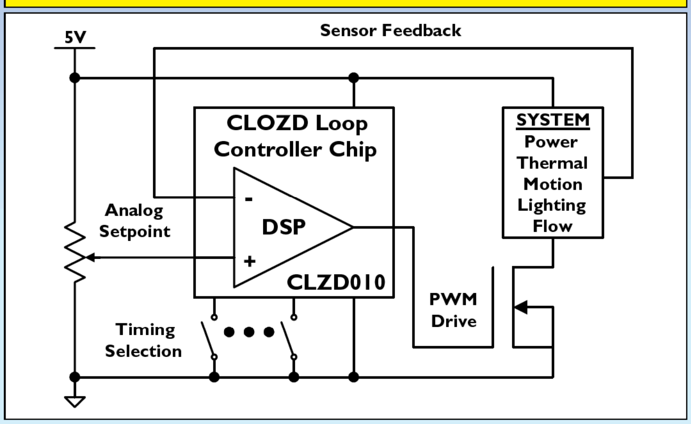
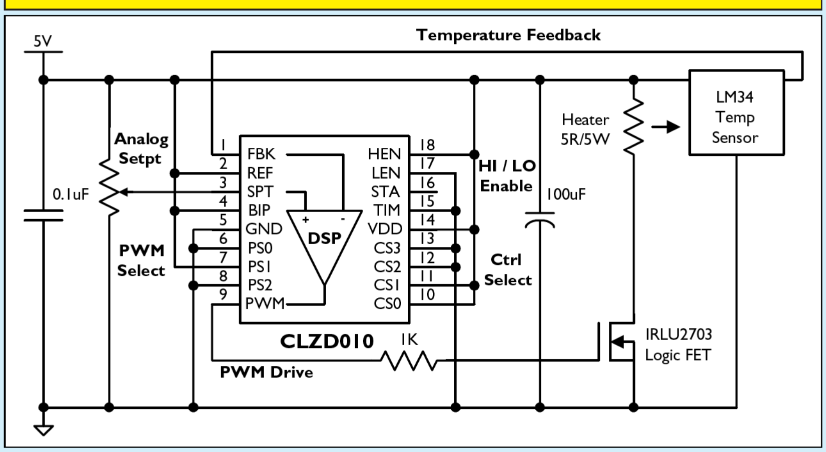


Figure 2. A thermal controller (for a 5 W heater).
PWM = 488 Hz (PS=010, BIP=1) CLOZD = 134S (CS=0011, TIM=0).



Thermal Controller

Thermal control systems are challenging because they have low level signals, long time constants, and multiple lag elements that can cause overshoot. However, the one shown in Figure 2 is quick and easy to configure for high performance with a few inexpensive parts. The duty cycle (percentage time

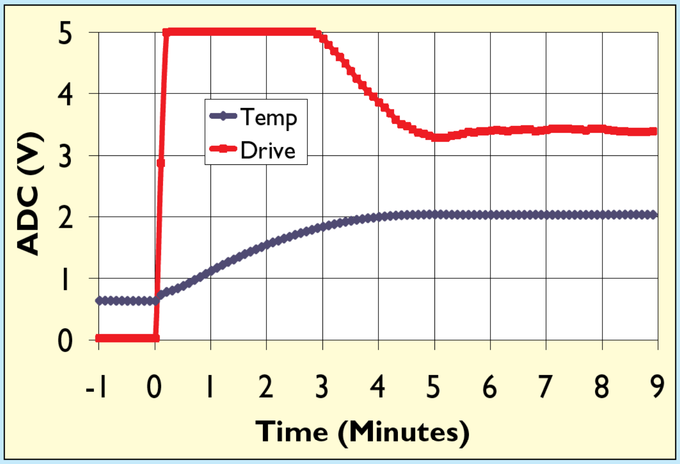


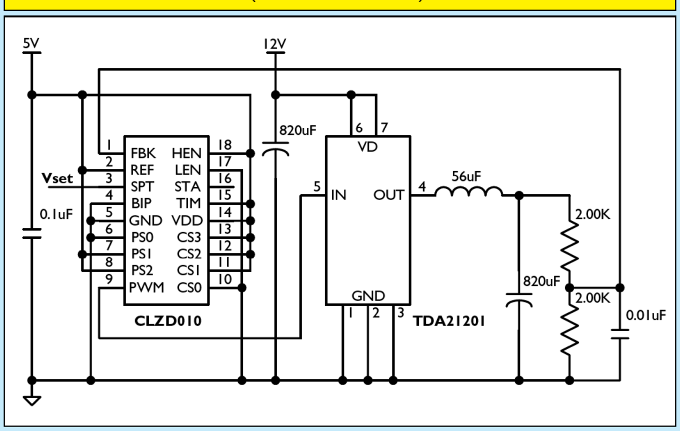
Figure 3. Temperature feedback and filtered PWM drive.

conducting) of the FET switch is adjusted until temperature feedback from the LM34 sensor is equal to the desired setpoint of the potentiometer. PWM frequency is set by the state of pins PS2-PS0 on CLZD010 while loop timing is set by pins CS3-CS0. Pins HEN and LEN are high and low enables.

The logic FET can be driven directly because low frequency PWM (PS2-PS0=488 Hz) is used with slow transitions (1K Ω gate resistor). Control timing was estimated by applying power to the heater and monitoring the temperature response. It took over 10 minutes for temperature to settle near its final value in an open-loop configuration. The temperature went from ambient to about two thirds of its final value in two to three minutes ($\tau = 1\text{-}e^{-1} \approx 63\%$), so the timing of the system was set slightly faster (CS3-CS0=134 S).

Figure 3 shows the filtered (average) PWM drive and the temperature FBK response as a function of time. Notice that drive is high while the loop error (FPT-FBK) is large, but decreases prior to the temperature reaching its final value of 200°F (FBK=2 V) for fast response without overshoot.

Figure 4. A switching power amplifier (10 V/10 A). PWM = 31.2 KHz (PS=110, BIP=0) CLOZD = 128 mS (CS=1110, TIM=1).



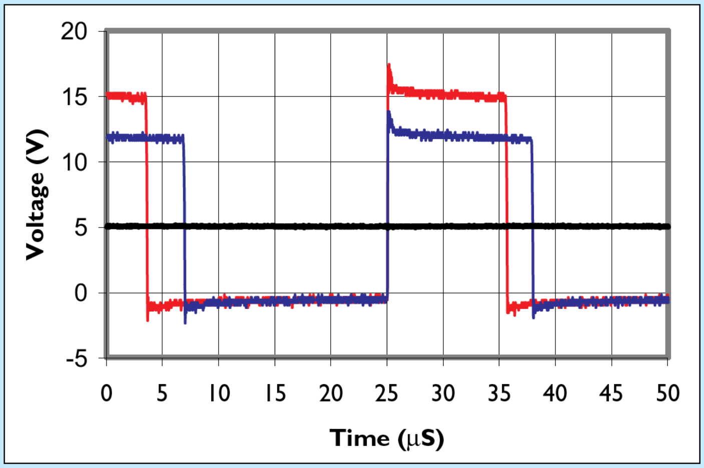


Figure 5. PWM drive waveforms for constant 5 V output with 12 V and 15 V supplies.

Power Amplifier

Figure 4 illustrates a power amplifier that sources or sinks current while maintaining constant output voltage at twice (1+2 K/2 K) the analog setpoint (Vset). This circuit is a switching converter that behaves like a low frequency (100 Hz) high power (10 V/5 A) op-amp. It requires few parts that are inherently robust because critical functions are integrated, including digital signal processing, power switching, and thermal shutdown.

The half-bridge driver TDA21201 converts PWM logic levels to a high power pulse train that is averaged to a DC level by the output LC filter, as shown in Figure 5. The LC response is fast and susceptible to ringing, so high speed sampling and control calculations are required. For this reason, the 128 µS control setting is used despite the 214 µS time constant of the system ($\tau = LC^{1/2}$).

Figure 5 illustrates that more drive (higher duty cycle) is required at a lower supply voltage (12 V versus 15 V) to maintain constant output voltage.

Bidirectional Controller

Figure 6 illustrates a thermal controller that uses a Thermo-Electric-Cooler (TEC) or Peltier Cell to heat (PWM>50%) or cool (PWM<50%), depending on current direction through full-bridge driver LMD18201. This circuit is useful for applications requiring variable temperatures that include ambient. The full-bridge has two outputs that switch out-of-phase; one is low while the other is high. Both filtered outputs are equal at half the input voltage when

PWM=50%, so no power passes through the TEC. By tying the bipolar BIP pin of the controller high, the PWM initializes at 50% duty cycle rather than the usual 0%.

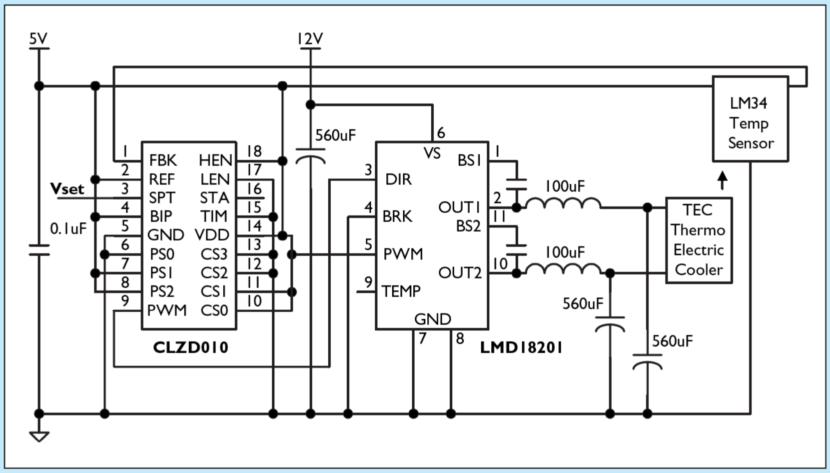


Figure 6. A bipolar thermo-electric cooler (12 V/3 A Peltier cell). PWM = 31.2 KHz (PS=110, BIP=1) CLOZD = 134 S (CS=0011, TIM=0).

PC USB Control

Two chips under $10.00 — each with free software drivers — enable the PC-based controller in Figure 7. The USB to serial converter provides the PC interface to the FlexController™ System-On-Chip (SOC), which commands setpoint and records system response through Visual Basic, while real-time control is performed by the CLOZD chip.

The FT232BM chip includes the hardware and PC drivers to communicate with microcontrollers through a USB port. The FCIC010 FlexController SOC combines the peripherals of a microcontroller with the ease of Visual Basic (or C++) programming through FTview™ Active X Control. These devices save valuable time by eliminating tedious low level programming and enabling customization through intuitive graphical development software.

```
Visual Basic code for control from PC USB:


Private Sub FTview1_NewData()
 FTview1.PWMduty = Setpoint         ' Write duty cycle
 Feedback = FTview1.AD0volt         ' Read AD0 voltage
 Write #1, Time, Setpoint,Feedback  ' Save data to File
 FTview1.UpdateCmd = True           ' Update Control SOC
End Sub
```

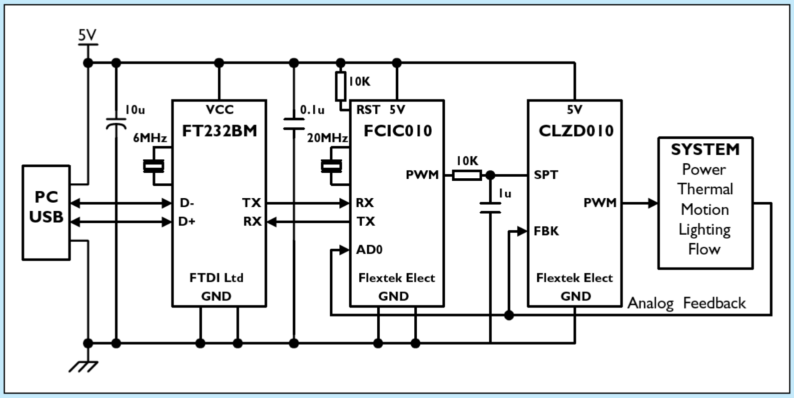


Figure 7. Closed-loop controller with PC USB interface.

Automated Control Advantages

Closed loop control may be the most common and, yet, the most challenging task in electronics. By automating this task with versatile interfaces that are easy to use, a wide range of custom applications are quickly satisfied. Users save time and money by quickly configuring the same components for multiple applications. This allows savings on parts by purchasing in volume, reduced development time by reapplying familiar technology, and increased reliability by using proven components.

CLOZD Loop Controller utilizes advanced DSP techniques and algorithms to satisfy challenging real time control applications quickly and easily. Other methods and products require extensive programming and complex frequency-domain analysis. Configure the controller for a broad range of power, thermal, motion, lighting, and flow applications by selecting appropriate pin settings.

The CLSD010 control chip may be purchased for $5.95 with complete data sheet and application notes from **www.flex-tek.com** Other components referenced in this article may be purchased from **www.digi-key.com**, except the Peltier, which is available from **www.allelectronics.com** NV

About the Author

David Caldwell is the founder of Flextek Electronics, and has authored over a dozen papers and articles on power and control. You can reach him at djcaldwell@flex-tek.com