FLEXIBLE POWER CONVERTER AND PROCESS CONTROLLER

David Caldwell
President
Flextek Electronics

Abstract

Flexible power converter satisfies wide variety of tasks quickly and easily, including Point-Of-Load applications and challenging process controls. The power stage has dual filtered half-bridges that can be run independently or paralleled for higher current and lower ripple, as well as full-bridge or sequentially switched. On-board intelligence is accomplished through an embedded DSP preprogrammed as a flexible closed loop controller. This patented product may be applied as a digital power supply, TEC thermal regulator, DC motor driver, or controller for lighting and flow applications.

Highlights

· Power stage is configurable by pin settings
· Voltage regulation or external feedback
· Single parameter adjustment for closed loop control
· Simple interfaces that are intuitive and familiar
· Stand-alone operation or serial communication
· Multiple applications without programming

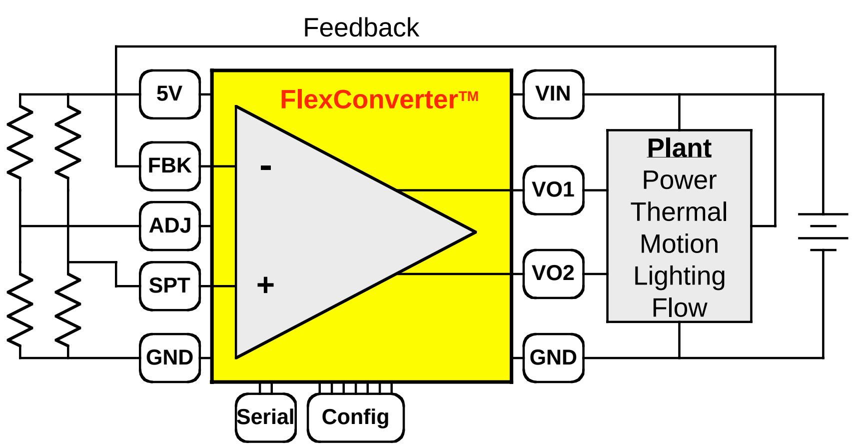


Figure 1. Flexible Power Converter and Process Controller
(Power Amplifier with Configurable Outputs and Single Control Adjustment satisfies Multiple Applications without Programming)

Digital Power Control Objectives

Designers often spend excessive time on custom applications to yield disappointing results because dedicated analog chips are too specific and programmable digital parts are too general. A flexible power converter has been developed with dedicated features that are quickly configured to satisfy a wide variety of tasks without programming. This product demonstrates the potential of digital control in power electronics by satisfying basic objectives:

1) Simplicity and Balance
    a. Strive to satisfy rather than impress
    b. Newer is not necessarily better
    c. Best solution is simplest one that works
2) Convenient User Interfaces
    a. Shield users from operational complexity
    b. Serial port for advanced features only
    c. Evaluation kit speeds development
3) Flexible Control Capabilities
    a. Digital control loop for recurring compensation changes
    b. Digital management (outside loop) for low power
    c. Options enable innovation and standards limit progress

The first objective points out that digital power control should be applied to satisfy needs that are not easily accomplished through traditional approaches. The burden of going digital (component cost, overhead power, and development time) should be justified by engineering rather than marketing. Products that provide real advantages will succeed, independent of control methodology.

The concept of simplicity is extended to the critical user interface in the second objective. If a customer has to provide a computer with special hardware and software drivers to simply adjust output voltage, then the advantage of going digital is questionable. While a serial interface can be useful, it should be reserved for advanced features. Components that require special interface hardware or custom PCB are overly burdensome to evaluate so manufacturers should supply kits.

Finally, most converters have control parameters set at the factory for a specific power stage and filter so a digital loop is not justified. Low power applications often require a low frequency micro for minimal consumption to manage voltage, sequencing, and limits. Since the primary advantage of digital control is flexibility, manufacturers cannot assume they have considered every potential application. Provide customers with options that allow them to innovate, and standards will naturally evolve through product success.

Configurable Power Converter

The FlexConverter™ Evaluation Kit shown in Figure 2 can be easily applied in minutes to satisfy practical power conversion and process control challenges. Advanced digital algorithms are available through familiar analog interfaces that enable unique solutions to difficult problems. The small size and low cost of the power module make it suitable for volume production while the evaluation board speeds development.

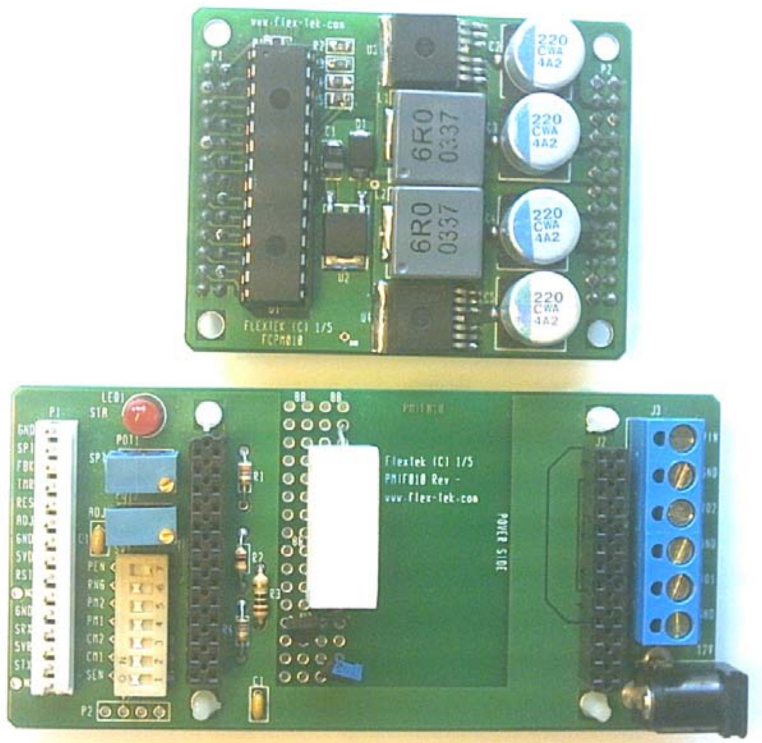


Figure 2. FlexConverter™ Evaluation Kit Photo
(Compact Power Module Plugs into Evaluation Board for Convenient Operation)

The power module is 2.5in X 1.9in with 0.1in spaced pins to fit standard prototype boards or solder to PCB for production. Input voltage range is 10–14V and output is 0–12V. Total output current is 12A through the two phase shifted outputs. Full load efficiency is 92% and recovery time to stepped loads is less than 100uS. The optional 4.0in X 1.9in evaluation board enables quick and easy product familiarization.

Figure 3 is a block diagram of the FlexConverter™ Evaluation Kit that illustrates basic operation. The power stage has dual filtered half-bridges that can be run independently or paralleled for higher current and lower ripple, as well as full-bridge or sequentially switched. The evaluation board adds convenient screw terminals, power plug, pots, switches, LED, test points, with lighting and thermal experiments for demonstration.

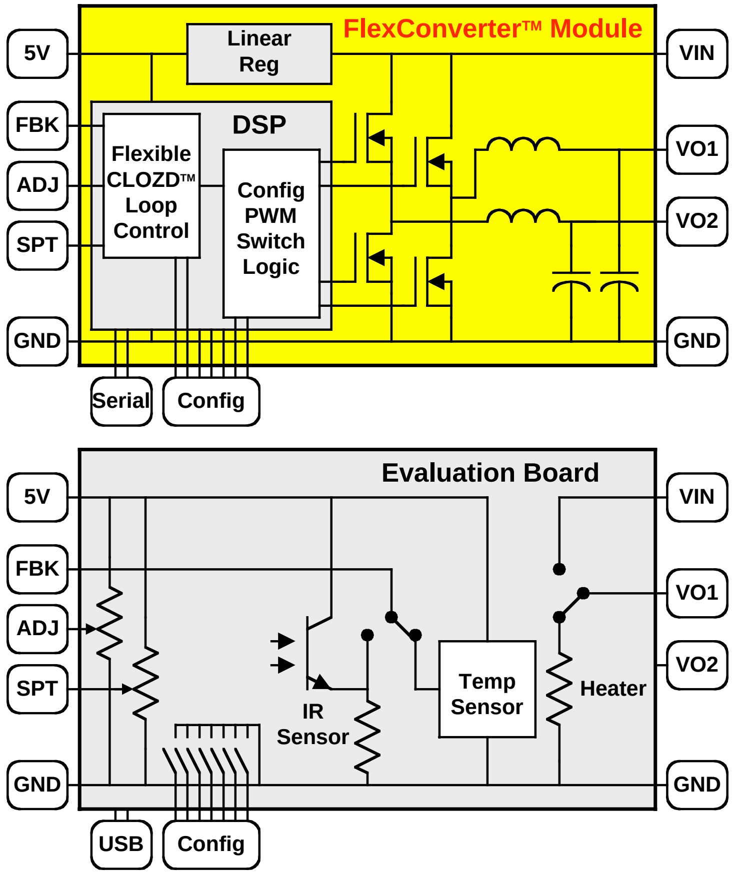


Figure 3. FlexConverter™ Evaluation Kit Block Diagram
(Evaluation Board Contains Optional Lighting and Thermal Experiments)

On-board intelligence is accomplished through an embedded DSP preprogrammed as a flexible closed loop controller. This patented product may be quickly applied as a digital power supply, TEC thermal regulator, DC motor driver, or controller for lighting and flow applications. Configuration is through pin settings for stand-alone operation, while an optional serial port enables processor or PC communication.

Flexible Closed Loop Controller

Constant voltage is required in only a subset of electrical applications, while voltage is varied to regulate loads (thermal, motion, lighting, and flow) in most other systems. Losses accumulate as power is first processed by a voltage converter then by a load regulator. Not only do electrical energy losses accumulate, so do expensive engineering losses. The power switches and closed loop controllers in voltage converters and load regulators can be combined to save both component and development costs.

Figure 4 shows the voltage drive and temperature response of the FlexConverter™ Evaluation Kit thermal experiment, both open and closed loop. CLOZD™ (Caldwell Loop Optimization in Z-Domain) is the DSP algorithm that compares the feedback FBK signal to the setpoint SPT command and calculates the appropriate output voltage VO1 to equalize the two.

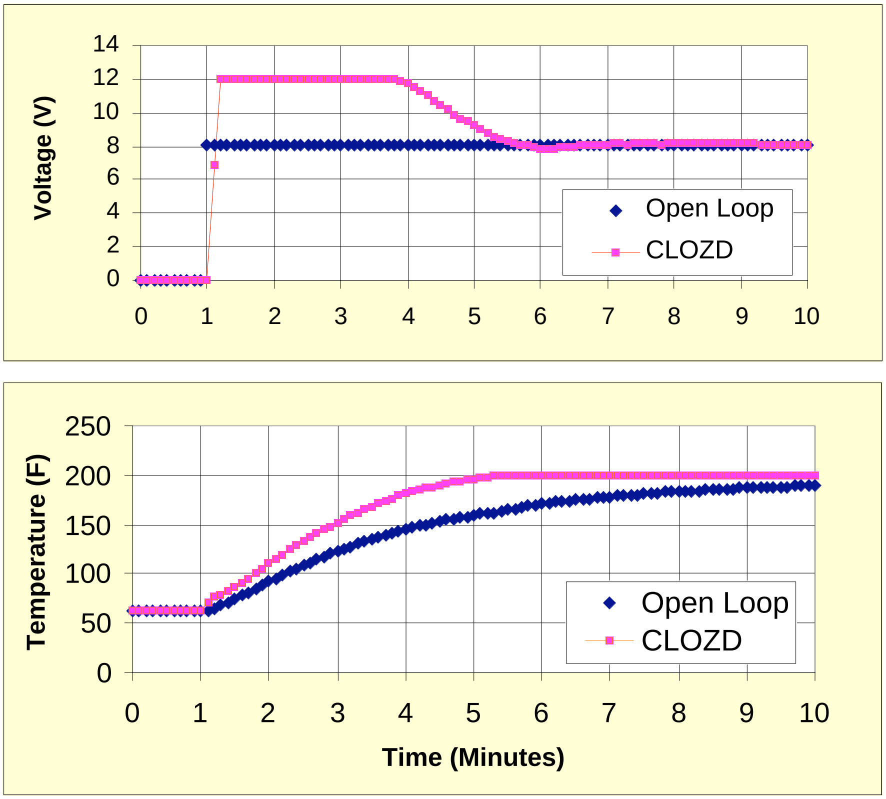
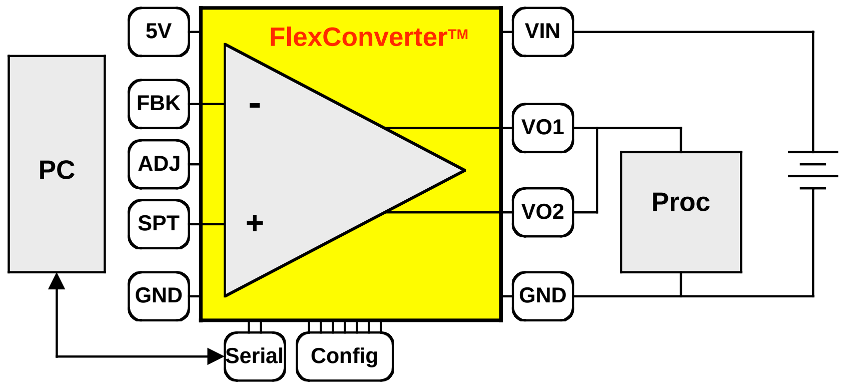


Figure 4. FlexConverter^{TM} Evaluation Kit Thermal Response
(CLOZD^{TM} Loop vs. Open Loop - Voltage Drive and Temperature Response)

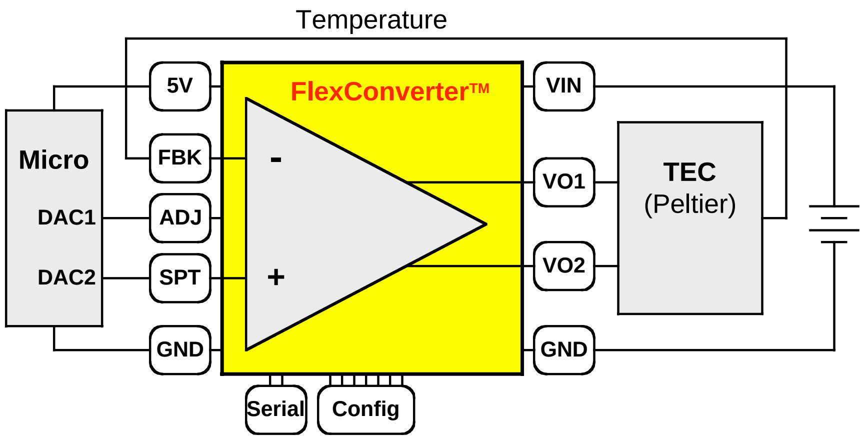
The CLOZD^{TM} algorithm is adjusted for a specific application through the single ADJ pin, in comparison to the three parameters of the analog-based PID technique. Another simplification is that the control adjustment is an intuitive time-domain setting rather than complex frequency-domain settings. Simply inspect the open loop time constant of the system (approximately 180 seconds to reach 63% of final value in Figure 4) and look up the voltage setting for ADJ pin from FlexConverter^{TM} data sheet.

Applications and Advantages

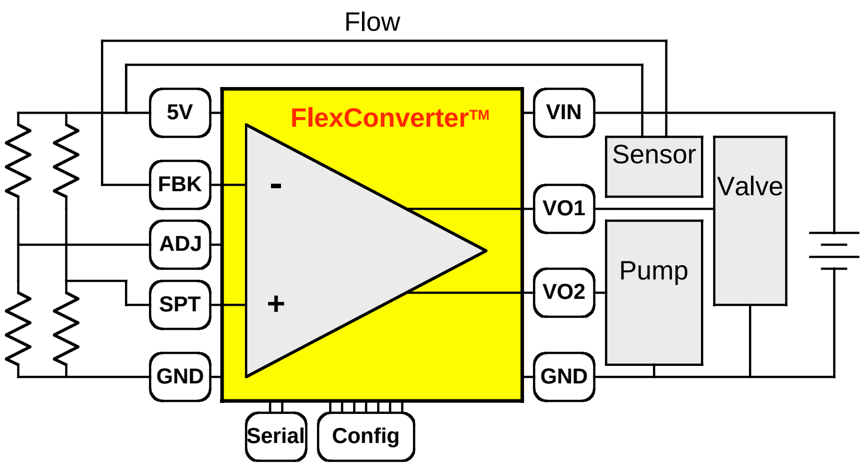
Figure 5 illustrates few of the countless FlexConverter^{TM} applications. Circuit A is a PC-based POL converter with parallel phased outputs to increase current and reduce ripple. By grounding the appropriate configuration pins, the outputs are applied full-bridge in circuit B for bi-directional thermal control (cooling or heating). The last example utilizes sequential drive where the valve is first gradually opened then the pump is linearly powered to maintain constant flow. Alternately, the two converter outputs could be set independently as a dual power supply.



A. PC-Based Point-Of-Load Converter with Paralleled Outputs



B. Bi-directional Thermo-Electric-Cooler with Full-Bridge Power Stage



C. Automatic Flow Controller with Sequential Drives

Figure 5. Example FlexConverter™ Applications

Consider that the most popular electronic components in history have been the voltage regulator, op-amp, and microcontroller because most projects require power, control, and customization. A system containing these components usually requires significant time and expertise to design and apply. However, combining the best features of these components into a single product simplifies the entire process.

A configurable power stage with adjustable controller is quick and easy to apply, and inexpensive because components are common and support is minimal. Design-from-scratch solutions reduce component cost but require extensive development efforts. Digital power converters are emerging but lack essential features for control applications. Programmable real-time controllers are useful but steep learning curves and significant software cycles drive up total costs.

FlexConverter™ fills the gap between digital power converters and programmable real-time controllers to satisfy a variety of power conversion and process control applications quickly and easily. Using the same product in a variety of applications reduces component cost through volume purchase, reduces development time by re-applying familiar technology, and increases reliability by utilizing proven components.

References

[1] D.J. Caldwell, “Flexible Power Amplifier Doubles as Process Controller,” Electronic Design Brief, November 29, 2004.
[2] D.J. Caldwell, “CLOZD™ Loop Controller Chip CLZD010,” Component Data Sheet, www.flex-tek.com, Feb. 2004.
[3] D.J. Caldwell, “Flexible Closed-Loop Controller,” U.S. Patent 6697685, Feb. 2004.
[4] D.J. Caldwell, "Power Control: Digital Flexibility at Analog Prices," Power Systems World Conference, Santa Clara, CA, November 1998.
[5] D.J. Caldwell, "Power Goes Digital," EDN Magazine, August 18 2005.
[6] D.J. Caldwell, "Microcontroller Enables Digital Control in SMPS," Power Electronics Technology Magazine, February 2004.