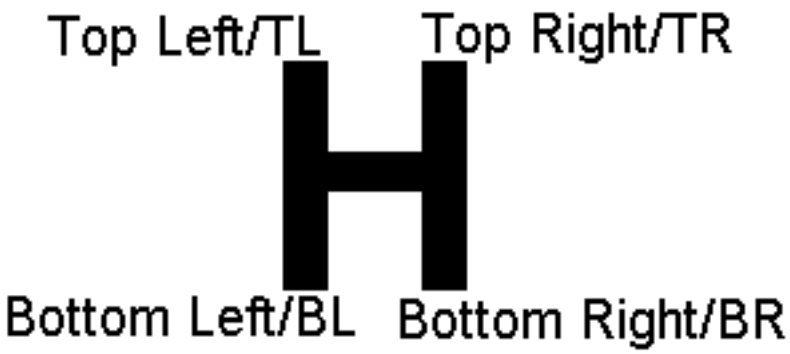
H-Bridges & Class-D

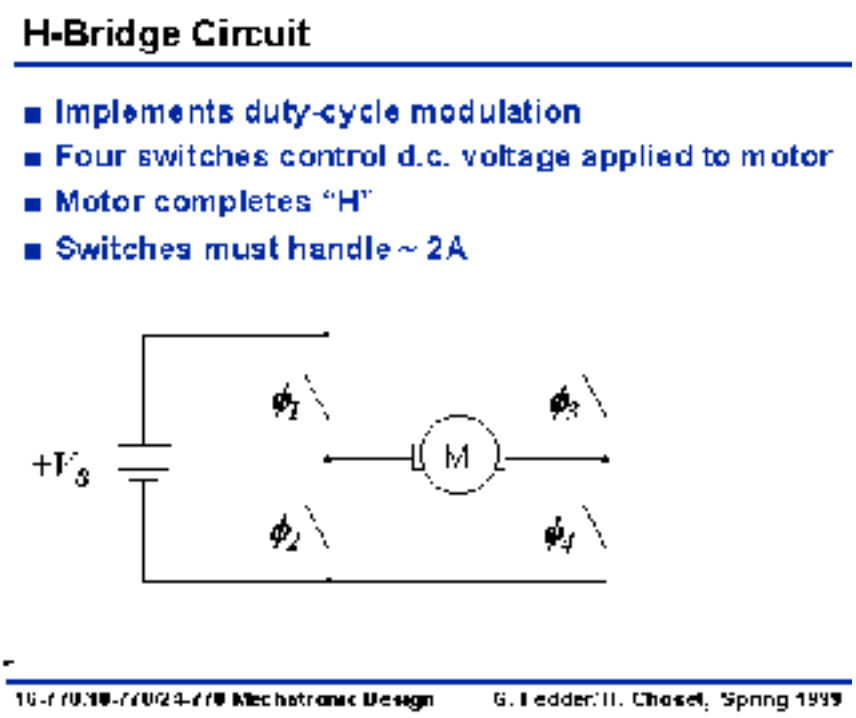
by Bob Paddock

This month's topic, H-Bridges, was brought about because I needed to find a small H-Bridge device. As I looked around the H-Bridge pages, I kept running into applications covering Class-D power amplifiers, which seemed like it would make a interesting topic. To many people, hearing Class-D brings about thoughts of audio amplifiers, but it does have other interesting uses.

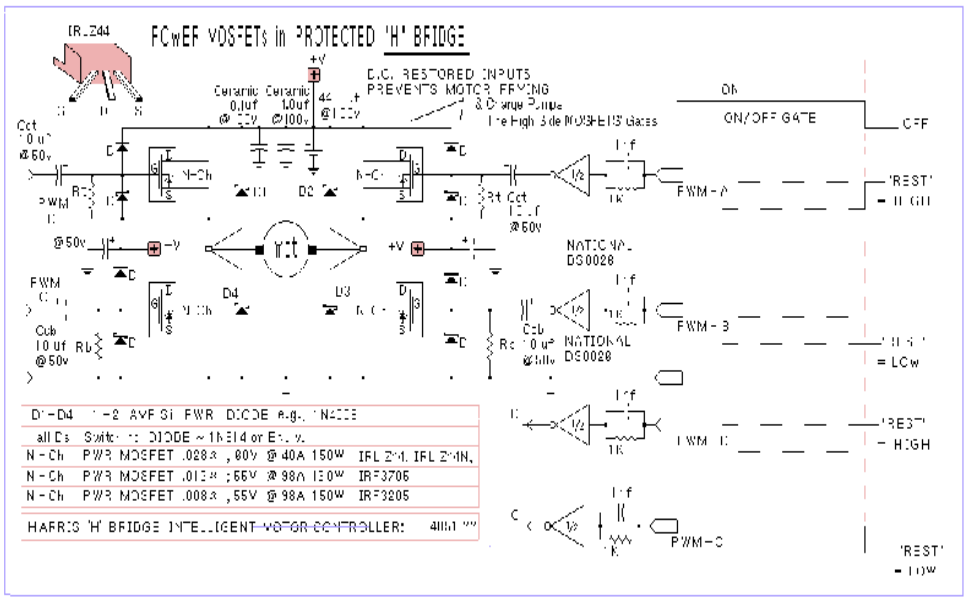
But before we tackle that, let's cover the basics, brought to you by the letter H



The course in *Mechatronic Design* by instructors: Prof. Gary Fedder (ECE and Robotics) and Prof. Howie Choset (Mechanical Engineering and Robotics) has a good introduction to H-Bridge Motor Drive Electronics as part of their lecture series.



The *ECE 480 Home Page Where a Picture is Worth a Thousand & Twenty-four Words* is worth a stop when you are looking for any kind of circuit, even an H-Bridge. They show a simple method to prevent your H-Bridge from becoming a fuse tester. The fuse tester mode happens when both switches in the same leg of the H are turned on simultaneously, causing a short of the power supply to ground.



The *Using MOSFETs* page is dedicated to learning about MOSFETs in

DC motor control and starts with a short MOSFET primer, then progresses into H-Bridges of different types.

Bill W.'s page is about building your own affordable CNC system using low-cost or free step and direction software, and closed loop servo control electronics. His H-Bridge theory section sums up the H-Bridge:

> There are two kinds of amplifiers for driving motors, linear and PWM. One of the benefits of linear amps is they produce a lot less electrical noise that can interfere with other electronics. The drawback is that they are bulky, expensive, and generate a lot of heat. PWM amps are just the opposite they are small, inexpensive and generate lots of electrical noise. The reason PWM amps run cooler is because most of the time the transistors are in cut-off or saturation where they generate the least amount of heat.

While putting together this web page, one of the areas that kept coming in during my searching was fields related to robotics. One of the more interesting areas that covered H-Bridges is BEAM machines. Beam-Tek describes BEAM technology:

> "The ideas and technology underlying BEAM Robotics is one of anti-complexification. Most of the technological challenges facing robotics is the environment these machines are immersed within is highly complicated and ever-changing. Forget the brain, let us focus on a simple stimulus-response based ability within a machine. Smart bodies that can handle the real world on their own. We can work on the brain later, but the body and nervous system should be the beginning and the foundation for all work in living machines."

B E A M - R o b o t i c s - T e k

Mark W. Tilden gives an example relevant to the subject at hand in his Biomech Motor Bridges, with a circuit based on an SCR-like current amplifier arrangement which, when biased correctly, works quite well for most push-pull inductive actuators from solenoids to stepper motors.

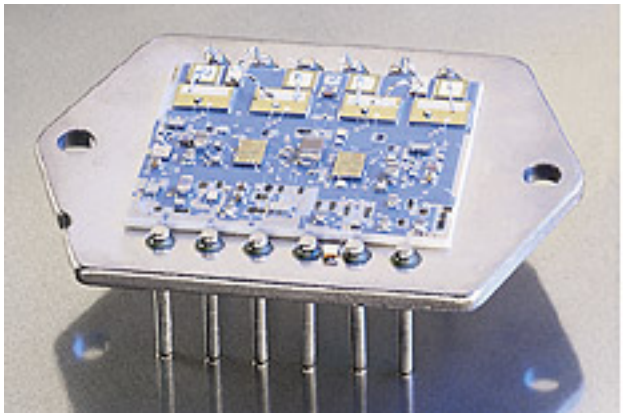
Check out the other BEAM areas on Motors and Motor Drivers and the BEAM Robotics Web Ring.

A Web Ring links member web sites together to transform their sites into linked circles. Their purpose: to allow more visitors to reach them quickly and easily. To your benefit, you can locate related sites that don't always show up in the search engines.

Allegro MicroSystems Inc. offers several Bridge Motor Drivers. For example: Dual PWM Full Bridge w/Brake.

Apex Microtechnology Corporation specializes in high-power and high-voltage hybrids.

The Apex Circuit Design Center enables you to quickly and easily match your application to a specific Apex part. Motion control, deflection, piezo drivers, and others are all here in pdf format. You can view a part-specific schematic or download the entire collection for offline browsing.



The new SA08 and SA18 hybrid PWM amplifiers from Apex Microtechnology operate off a wide 16-V–500-V single supply that affords their design in applications without transformers where the wall outlet voltages ranged from 115–230 VAC. Both the full H-bridge SA08 and half-bridge SA18 provide 20 A of output current,

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Composite Modules Industries, specializes in high-reliability medical electronics. The need for intelligent motor controllers and smart power modules capable of surviving autoclave sterilization is a necessity for surgical electronic devices and equipment. CMI guarantees its electronics to exceed 3,000 autoclave cycles.

H-BRIDGE POWER DRIVER	**FH1208S8**

Features:

- Single supply voltage 20 to 80 V @ up to 12 A

- Thermal protection
- Crossover current protection
- TTL-CMOS inputs
- Electrically isolated package

QUADPAC N-CHANNEL POWER H-BRIDGE	Q2010N

Features:

- Isolated hermetic package
- Low Rds(on)
- 20 A source current
- 100 V breakdown voltage

The Q2010N is a packaged set of four N-Channel MOSFETs. It is an ideal replacement in applications requiring multiple discrete FETs. This hermetically packaged product features the latest advanced MOSFET and packaging technology. The four MOSFETs are electrically isolated from the package. The small size allows for a high degree of flexibility in circuit design and eliminates the need for isolation spacers and their added thermal resistance when mounting to a heat sink.

Harris Corporation has sold most of their Semiconductor line to Intersil, but no matter what you want to call them, they have some of the best tutorial papers on Class-D Audio.

The HIP4080 is a member of the HIP408X family of high-frequency H-Bridge driver ICs. The HIP4080 H-Bridge driver IC provides the ability to operate from 8 VDC to 80 VDC busses for driving Channel MOSFET H-Bridges. The HIP4080, packaged in either 20-lead DIP or 20-lead SOIC, provides peak gate current drive of 2.5 A. A combination of bootstrap and charge-pumping techniques is used to power the circuitry that drives the upper MOSFETs of the H-Bridge. The bootstrap technique supplies the high instantaneous current needed for turning on the power devices while the charge pump provides enough current to maintain bias voltage on the upper driver sections and MOSFETs.

HIP4080 80V/2.5A Peak, High Frequency Full Bridge FET Driver
HIP4081 80V/2.5A Peak, High Frequency Full Bridge FET Driver
HIP4080A 80V/2.5A Peak, High Frequency Full Bridge FET Driver
HIP4081A 80V/2.5A Peak, High Frequency Full Bridge FET Driver

AN9758 Multimedia, Cool Audio, Cool Media Understanding Multimedia Standards
AN9759 Multimedia, Cool Audio, Cool Media Signal Processing Blocks - A Tutorial

IP4080AEVAL2 Class-D Audio II Evaluation Board
HIP200ACREF 200W Class D Subwoofer Amplifier (Cool Audio)
HCA250ACREF 250W Class D Subwoofer Amplifier

HCA125ACREF 125/220 Watt Full Bandwidth Class D Amplifier

LinFinity has been acquired by Microsemi Corporation.

The LX1720 is a highly integrated switching Class-D stereo power amplifier controller IC with power and size features that make it ideal for multimedia computer applications, as well as other applications where high-fidelity sound is required. With input voltage ranging from 7-V–15-V, the LX1720 is designed to operate over the full 20 Hz to 20 kHz audio range. Signal distortion measurements using industry standard 1 kHz signal yields THD + noise levels < 1% (10 W output). Its high efficiency (>92%) eliminates the need for heat sinks while delivering more than 10 WRMS across 8 ohms per channel (20 WRMS stereo) with 0.1 ohm SO-8 power FETs.

AN-11.pdf LX1720: High-Efficiency Class-D, Stereo Audio Amplifier Controller IC.

AN-7.pdf A Simple Current-Sense Technique Eliminating a Sense Resistor. This App. Note can be used in many areas such as power supplies, it is not limited to H-Brdiges.

The Micrel Semiconductor MIC4467/4468/4469 Quad 1.2A-peak low-side MOSFET driver has applications in driving all four MOSFETs in an H-Bridge.

ON Semiconductor, formerly a division of Motorola, makes and delivers the power and interface semiconductors that turn technology on and connect it to your world.

AN1078: New Components Simplify Brush DC Motor Drives. A variety of new components simplify the design of brush motor drives. One is a brushless motor control IC which is easily adapted to brush motors. Others include multiple power MOSFETs in H-Bridge configuration, a new MOS turn-off device, and gain-stable opto level shifters. Several circuits illustrate how the new devices can be used in practical motor drives, in particular to control speed in both directions and operate from a single power supply.

AN1120: Basic Servo Loop Motor Control Using the MC68HC05B6 MCU A Proportional Derivative (PD) closed-loop speed control for a brush motor can be created using four integrated circuits, two opto discretes and less than 200 bytes of code. The use of an MCU in feedback-control systems is increasingly commonplace. It is justified when system flexibility is needed. For example, to accommodate varying drive motors or to allow wear parameters to be stored in EEPROM. This design is based on an MC68HC05B6 MCU and an

MPM3004 power MOSFET H-bridge.

AN1319: Design Considerations for a Low Voltage N-Channel H-Bridge Motor Drive Complementary MOSFET half-bridges are commonly used in low-voltage motor drives to simplify gate drive design. However, the P-channel FET in the half-bridge usually has higher ON-resistance or is larger and more expensive than the N-channel device. The alternative is to use an N-channel half-bridge, which uses silicon more efficiently and minimizes cost and conduction losses. The tradeoff is usually a more complex gate drive; this note looks at ways of minimizing gate drive complexity and also discusses diode snap, shoot-through current, and general design considerations.

The NEC µPD16837GS is a quad H-bridge driver IC using power MOSFETs in the output stage. Thanks to four built-in low on resistor H-bridge circuits, it is ideal for actuator driving. The 30-pin SSOP is ideal for small and thin applications.

National Semiconductor has a few Motor Control Bridges.

Product Folder (Datasheet)	Title	Package Type	Number of Channels
LMD18245	3-A,55-V DMOS Full-Bridge Motor Driver	TO-220	2
LMD18200	3-A,55-V H-Bridge	TO-220,SB Cerdip	2
LMD18201	3-A, 55-V H-Bridge	TO-220	2

The LMD18200 is a 3-A H-Bridge designed for motion control applications. The device is built using a multitechnology process that combines bipolar and CMOS control circuitry with DMOS power devices on the same monolithic structure. Ideal for driving DC and stepper motors, the LMD18200 accommodates peak output currents up to 6 A. An innovative circuit that facilitates low-loss sensing of the output current has been implemented.

The LMD18201 is a 3-A H-Bridge designed for motion-control applications. Current sensing can be achieved via a small sense resistor connected in series with the power ground lead. For current sensing without disturbing the path of current to the load, the LMD18200 is recommended.

The LMD18245 full-bridge power amplifier incorporates all the circuit blocks required to drive and control current in a brushed-type DC motor or one phase of a bipolar stepper motor. The LMD18245 controls the motor current via a fixed off-time chopper technique. A four-bit digital-to-analog converter (DAC) provides a digital path for controlling the motor current and, by extension, simplifies implementation of full, half, and microstep stepper motor drives. For higher resolution

applications, an external DAC can be used.

The Philips TDA5341 is a BiCMOS integrated circuit used to drive brushless DC motors in full-wave mode. The device senses the rotor position using an EMF sensing technique and is ideally suited as a drive circuit for a hard disk drive motor. The TDA5341 also includes a Voice Coil Motor driver (VCM), reset and park facilities and an accurate speed regulator. In addition, a serial port facilitates the control of the device.

SENSITRON SEMICONDUCTOR

Sensitron Semiconductor offers their SCP-3623 DUAL H-BRIDGE POWER MODULE 30 A@100 V.

Motor Control ICs Vishay Siliconix has a few H-Bridge parts (see table)

STMicroelectronics

Push-Pull Four Channel/Dual H-Bridge Driver L293

AN240/1288 Applications of Monolithic Bridge Drivers (pdf)
High-power monolithic bridge drivers are an attractive replacement for discrete transistors and half bridges in applications such as DC motor and stepper motor driving. This application guide describes three such devices—the L293, L293E, and L298—and presents practical examples of their application. The L293, L293E, and L298 each contain four push-pull power drivers that can be used independently or, more commonly, as two full bridges.

Controlling Voltage Transients in Full Bridge Drivers Applications AN280

Car Body Application Mirror Drive

STMicroelectronics Announce One-Chip Class D Audio Power Amplifiers.

The TDA7480 (10W) /TDA7481 (18W) /TDA7482 (25W) are single-ended, split-supply, Class-D amplifiers. The output of the amplifier is a high-frequency square wave (around 100 KHz), rail to rail, with variable duty cycle. The audio information is the average value of the output square wave. To obtain the audio signal, the output must be

low-pass filtered. The main issue of this amplifier is the low dissipated power (the high efficiency) compared to a normal class AB amplifier. The preamplifier provides the voltage gain of the overall amplifier. The second stage is the power stage, with a gain 1.5 times, that is the high efficiency Class-D amplifier. The Class-D amplifier stage is done with a multivibrator: with no signal it generates a 50% duty cycle square wave, with signal applied, it changes the duty cycle. The switching frequency is set by the voltage on pin 9 (DIP20) or pin 6 (MW15). The output power stage is done with N-ch DMOS power with the upper one supplied by a bootstrap capacitor.

Texas Instruments:

The TPIC0107B is a PWM-control intelligent H-bridge designed specifically for DC motor applications. The device provides forward, reverse, and brake modes of operation.

TPIC0108B Powerplus Control PWM control intelligent H-Bridge.

SN754410NE 1A Dual H-Bridge (pdf):

- 1-A output-current capability per driver
- Applications include half-H and full-H solenoid drivers and motor drivers
- Designed for positive-supply applications
- Wide supply-voltage range of 4.5 V to 36 V
- TTL and CMOS compatible
- Separate input-logic supply
- Thermal shutdown
- Internal ESD protection
- Input hysteresis improves noise immunity
- 3-state outputs
- Minimized power dissipation
- Sink/Source interlock circuitry prevents simultaneous conduction
- No output glich during power up or power down

A Tutorial of Class-D Operation:

A fully integrated Class-D amplifier, like the TPA005D02, amplifies an analog input signal through pulse width modulation (PWM) techniques. The PWM waveform is then filtered through a low-pass filter, which removes the 250-kHz carrier frequency leaving a clean, pure amplified signal for the audio speakers. This process can be easily dissected and explained in four stages.

Analog Applications:

Reducing the output filter of a Class-D amplifier. 19

The currently recommended second-order output filter for the TPA005D02 is 30% of the audio power amplifier (APA) solution cost. This application note details the second-order Butterworth filter and two reduced filtering techniques, each providing a different price/performance node. Design decisions based on the measured results and conclusions are drawn to provide practical solutions for applications.

Power supply decoupling and audio signal filtering for the Class-D audio power amplifier 24

Class-D audio amplifiers are similar to switch-mode power supplies in that both compare an input signal with a reference to create an error voltage that controls a pulse-width modulation (PWM) circuit. This application note describes proper decoupling of the power supply, selection and implementation of audio input and output filters and some basic layout considerations for the TPA005D14 Class-D stereo power amplifier.

TI's Class-D Audio Power Amplifiers

Audio Amplifier Technologies, Class-D:

Class-D amplifiers process analog signals using PWM techniques, which is the key behind Class-D amplifiers' increased efficiency. The PWM signals are applied to power DMOS H-bridges, which provide high-output current capability. High-frequency square waves of constant amplitude, but varying width, are output from the IC. These pulses of varying widths contain the audio information. The output signal must be low-pass filtered to isolate the audio information from the high-frequency signal. Proper filtering assures the quality of the sound produced by the system. For a more detailed discussion, please see the Tutorial of Class-D Operation.

Class-D Amplifier Efficiency:

The efficiency of Class-A and -AB amplifiers is constrained by the bias current needed in the output stage. Bias current and audio performance are directly proportionate in Class-A and -AB amplifiers. This wasted current is dissipated as heat in the amplifier and must be extracted from the IC with the use of a heat sink. Since Class-D amplifiers do not have a linearly biased output stage, their efficiencies are much greater, making them ideal for use in battery-operated systems. The use of a Class-D amplifier can extend the life of a battery by three times over the older Class-AB linear amplifiers.

EVMs/Software/Application Notes:

To help designers implement Class-D audio power amplifiers, TI has developed an evaluation module (SLOP223) fully compatible with its APA Plug 'n Play Platform, the only one of its kind in the industry. Also available is the Audio Power Analysis Program. The software tool helps designers make quick and accurate calculations on power requirements and thermal data using real .wav files.

To help maximize sound quality, a comprehensive application note on low-pass filtering will be available later in the fourth quarter of 1998. Full documentation for the TPA005D02 EVM includes a User's Guide with reference designs and schematics. Gerber files are available upon request.

TPA005D02, 2-W Stereo Class-D Audio Amplifier

Mono Configuration of the TPA005D02 Class-D Audio Power Amplifier

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Unitrode Corporation has several unique application notes dealing with H-Bridges.

TI has announced plans to acquire Unitrode Corporation.

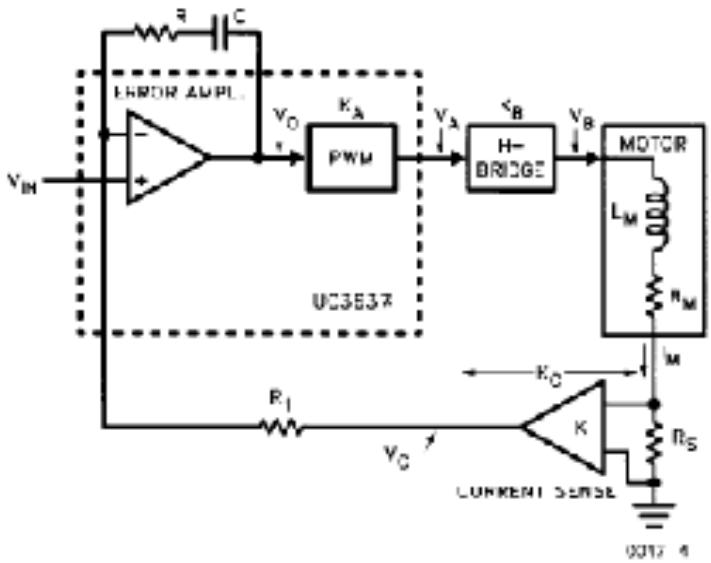


Figure 4. Block Diagram of the Complete Current-Control Loop

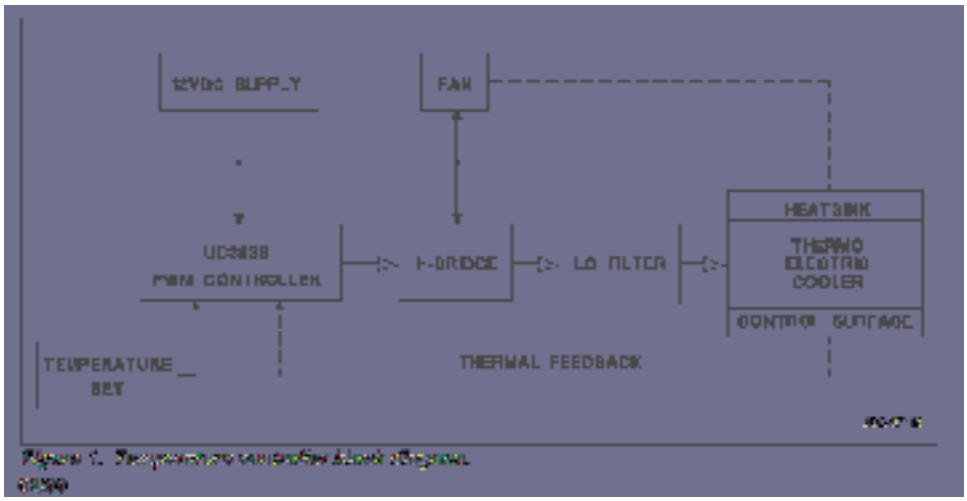
UC1637/2637/3637 Switched Mode Controller for DC Motor Drive

The UC1637 switched mode controller for DC motors is one of several integrated circuits offered by Unitrode for motor controls. This application note presents the general principles of its operation and the circuit details that optimize its use. As an illustration, we will carry out an actual design that will involve not only the UC1637, but also a power H-bridge using MOSFET transistors, and a modern DC motor tachometer.

A High Precision PWM Transconducance Amplifier for Micro-stepping Using Unitrode's UC3637 has more information as well.

Closed Loop Temperature Regulation
Using the UC3638 H-Bridge Motor Controller and
Thermoelectric Cooler

Class-D Amplifier for Thermoelectric Devices DN-76



Have you ever wanted to test an IC over temperature, but couldn't put the entire application circuit in the oven? Maybe you needed to access critical circuit nodes for troubleshooting, or observe the effects of temperature on only one component. Freeze sprays and hair dryers may be good for benchtop troubleshooting, but the temperature (and temperature slew rate) is highly uncontrolled and may actually damage the part. Forced air systems which direct temperature-controlled air to a specific area are available, but they are large, cumbersome, and expensive. What is needed is a portable, low-cost, temperature-forcing system.

One solution is to use a thermoelectric cooler. Thermoelectric coolers employ the Peltier effect, acting as small solid-state heat pumps when a DC current is passed through them. They are relatively small, flat devices that transfer heat from one side to the other. The direction of heat transfer can be reversed, for heating or cooling, by simply reversing the direction of the current. The amount of heat transfer is controlled by the magnitude of the current. A temperature difference achieved using a single element if proper heat sinking is provided on one side of the device. Larger temperature gradients can be produced by stacking multiple elements. They can be used effectively as part of a closed-loop temperature regulation system.

In high-voltage load driving applications, an H-Bridge must provide the requisite level of power dissipation, whilst minimizing use of PCB space. The new ZHB safely dissipates 2 W under normal DC conditions, when mounted on a full copper PCB measuring 50 mm × 50 mm. With the same physical profile as the industry standard SOT223 package, the SM8 H-Bridge package from Zetex offers a potential space saving of 300% over equivalent current capable designs and is

particularly useful in space-critical applications.

Zetex H-Bridge Devices (see table)

Automotive and Household Siren Driver Circuits - ZSD100 and Discrete 'H'-Bridge Minimum Parts Count Solution.

Surface mount H-Bridge faces up to high voltage rigors.

If you would like to add any information on this topic or request a specific topic to be covered, contact Bob Paddock.
