MICROCHIP

Intelligent Power Supply Design Solutions

Today, power supply designers must create power conversion products that offer greater efficiency, higher power density, higher reliability, advanced communications and sophisticated control features. And, as always, these products need to be developed and marketed quickly and at lower costs. Microchip offers a comprehensive set of Intelligent Power Supply solutions enabling you to meet these challenges.

What is an Intelligent Power Supply?

Traditional power supply designs use analog ICs with fixed functionality to provide regulated power. The intelligent power supply integrates a microcontroller (MCU) or Digital Signal Controller (DSC) for a fully programmable and flexible solution. Below are some examples of intelligent power supply functions:

- Digital on/off control for low standby power
- Power supply sequencing and hot-swap control
- Programmable soft-start profile
- Power supply history logging and fault management
- Output voltage margining
- Current fold back control
- Load sharing and balancing
- Regulation reference adjustment
- Compensation network control and adjustment
- Full digital control of power control loop
- Communications
- AC RMS voltage measurement
- Power factor correction

Example intelligent power supply applications include the following:

- AC-to-DC converters
- DC-to-DC converters
- DC-to-AC inverters
- Wireless power transmitters/receivers
- Uninterruptible Power Supply (UPS)
- Renewable power/pure sine wave inverters
- Battery chargers
- HID, LED and fluorescent light ballasts

Why Intelligent Power Conversion?

The use of digital control to implement power conversion functions offers many benefits to your designs and applications. These functions are enabled by performing power conversion control via reprogrammable software in conjunction with the performance and features offered by Microchip's Digitally Enhanced Power Analog technology plus our PIC® MCU and dsPIC® DSC solutions.

Intelligent Power Conversion Lowers the System Component Count

Valuable board space can be made available for magnetics and power components. Power supply control, regulation and protection functions can be incorporated into the same device. Auxiliary functions, such as fan control and data logging, are easily integrated.

Intelligent Power Conversion Allows Configuration for Different Applications

With intelligent power conversion, the power supply becomes a platform solution for many different applications. The power supply can easily be reprogrammed to support different output voltage levels, operating limits and control inputs. This reduces inventory overhead and the support required for multiple platforms.

Intelligent Power Conversion Increases System Efficiency

A power supply without intelligence is typically optimized for one operating point. A change in the operating load usually means a drop in system efficiency. An intelligent power supply design can adapt to load changes using many methods. These include a change of the power supply switching frequency and changes in the control loop configuration. Intelligent power supplies can monitor internal temperatures and supply power to cooling fans only when needed. They can also dynamically change the control loop behavior to provide the optimal system response for the load conditions.

## Intelligent Power Conversion Lowers Standby Power Consumption

Intelligence can be added to a power supply design that consumes only milliwatts or microwatts from the AC input when in standby. Electronic control inputs can be monitored while the bias supplies for the application are turned off.

How Can Microchip Help?

In addition to its local and global non-commissioned sales force, Microchip provides these products and resources for power conversion applications:

- 8-, 16- and 32-bit microcontrollers and 16-bit digital signal controllers
- High-side, low-side and synchronous MOSFET gate drivers
- Temperature sensors, fan controllers, digital potentiometers and op amps
- Analog PWM controllers including external control inputs
- High-voltage linear regulators and high-voltage interface products
- Serial EEPROM memory products
- Power conversion development tools, reference designs, algorithms and software
- Power conversion training and technical support
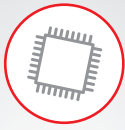
Silicon Solutions

- 8-, 16- and 32-bit microcontrollers and 16-bit digital signal controllers
- MOSFET gate drivers
- Analog and interface products
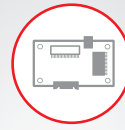- Non-volatile EEPROM memory

Technical Support

- Intelligent power supply design center
- Power conversion application notes
- Web seminars
- Regional training centers
- Intelligent power supply experts

Software and Algorithms

- Example code
  - AC/DC, DC/DC, DC/AC
  - Point of load
- Software examples for digital power control loops
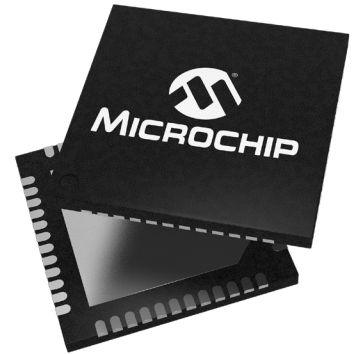- Highly optimized compensator libraries

Reference Designs and Tools

- Reference designs for different topologies and applications
- Design schematics
- Board layout files
- Low-cost development tools

Scalable Solutions for Power Conversion Applications

Microchip delivers everything a power conversion design engineer needs: low-risk product development, lower total system cost, faster time to market, outstanding technical support and dependable delivery and quality.

An intelligent power supply does not need to be complex or expensive. Offering MCUs and DSCs ranging from 6 to 144 pins, Microchip has an appropriate device solution for every application. Many simple tasks can be implemented with a low-cost MCU that contains basic peripherals. For more demanding applications, many of our MCUs and DSCs have innovative on-chip peripherals designed specifically for power conversion. These peripherals include fast PWM modules with special operating modes and high-speed Analog-to-Digital Converters (ADCs) for fast acquisition of power supply feedback signals.

Description	Technical Functions	Recommended Devices	Applications
Digital Control Of Analog Regulators	• Low-power standby • Programmable soft start • Power up sequencing	PIC10F PIC12F MIC45408 Integrated Power Module MIC28304 Integrated Power Module MCP16XXX Integrated Switching Regulators	Battery management Lighting Energy harvesting Embedded power conversion applications
Digitally Enhanced Power Analog (DEPA) Controllers	• High Input Voltage Capability • Integrated high current drive pins • Increased configuration capability • Programmable fault response	MCP19110 MCP19111 MCP19114 MCP19125 MCP19214 MCP19215	Battery charging Dimmable single or multi-string LED lighting Automotive power applications
Core Independent Peripheral (CIP) Hybrid Power Controllers	Flexibility to assemble multiple control topologies managed by a single CPU	PIC16F1764 PIC16F1769 PIC16F1777 PIC16F753	Management of solid state lighting solutions Advanced dimming solutions for automotive and building automation Battery charging Multistage power sequencing Smart power applications for IoT
Full Digital Power	• Dynamic control loop adjustment • Predictive control loop algorithms • Operational flexibility for different power levels	dsPIC33E dsPIC33C	Multi-stage AC-DC or DC-DC conversions Renewable energy Server and computing applications

Digital Control of Analog Regulators

For easy to implement digital management, single-chip regulators can efficiently perform a power conversion. Microchip's PIC and AVR® MCUs can implement on/off control, sequencing and monitoring of analog controllers or regulators. This approach is very effective in many battery management, lighting, energy harvesting and embedded power conversion applications.

Simple Control and Monitoring
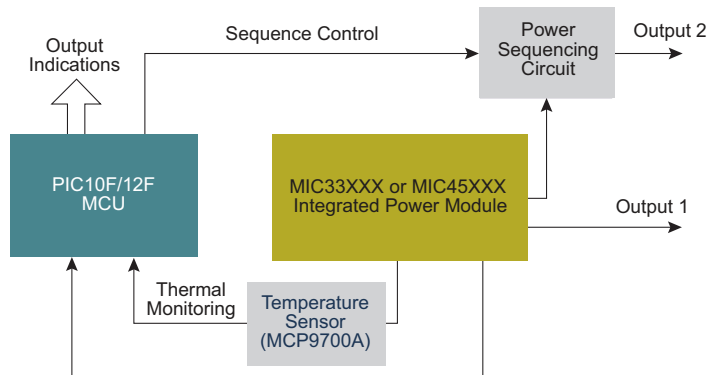
Digitally Enhanced Power Analog (DEPA) Controllers

In Digitally Enhanced Power Analog (DEPA) controllers, the analog control chip and PIC MCU are contained on the same die. This integration improves the accuracy, flexibility and speed of the digital management functions. DEPA solutions allow for a higher voltage input to the controller, eliminating the need for a bias supply; integrated high-current drive pins, eliminating the need for external driver chips; and a dramatic increase in the degree of configuration in the analog control loop, increasing the versatility of the design. The benefits include dynamically adjustable frequency, output level, current limit, over- and under-voltage protection levels. Combining these benefits with programmable fault responses results in optimal operation based on the real-time line, load and temperature conditions. DEPA-based intelligent power supplies are ideally suited to battery charging, dimmable single or multi-string LED lighting and automotive power applications.

MCP19119 Block Diagram
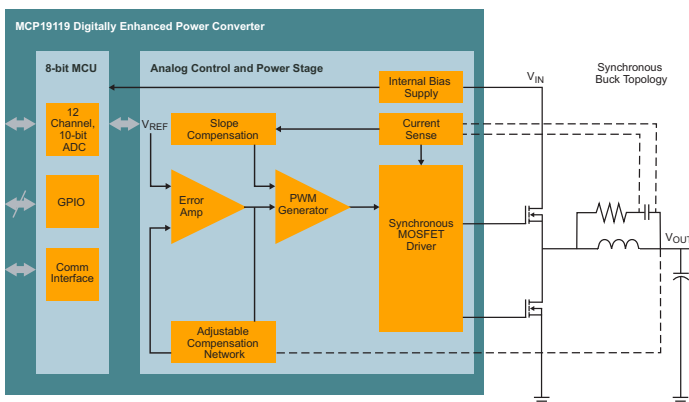
The MCP19119 Digitally-Enhanced Power Analog Controller combines the capabilities of the PIC mid-range microcontroller core with high-voltage, analog PWM control loop. This device contains digital registers to configure most power supply operating points: frequency, dead time, output voltage, current limits, over-voltage and under-voltage lockout. The operation of the control loop can be adjusted on the fly by the microcontroller, based on the power supply operation, digital inputs or external environmental variables measured through the on-board ADC. Properly calibrated, this is an extremely accurate and flexible intelligent power solution with a minimal device count.

Core Independent Peripheral (CIP) Hybrid Power Controllers

The analog control loop can be implemented efficiently in a PIC MCU taking advantage of the most recent set of Core Independent Peripheral (CIP) blocks optimized for power conversion applications. Capable MCU models (see product list below) implement a hybrid approach to power control by combining the flexibility of analog and digital peripherals that can be configured (at runtime) to assemble a large variety of topologies under the control of the microcontroller. CIP-hybrid controllers do not integrate FET drivers thereby leaving the developer maximum flexibility on the selection of power and voltages. Since CIPs are designed to operate independently from the core, once configured, they allow full use of the processor CPU for communication and coordination tasks while delivering optimal power supply performance/features. Up to four independent power conversion stages can be managed by a single controller. This is very well suited for management of smart (solid state) lighting solutions, advanced dimming solutions for automotive and building automation, battery charging, multistage power sequencing and smart power applications for the Internet of Things.

### Precision LED Dimming Engine Application
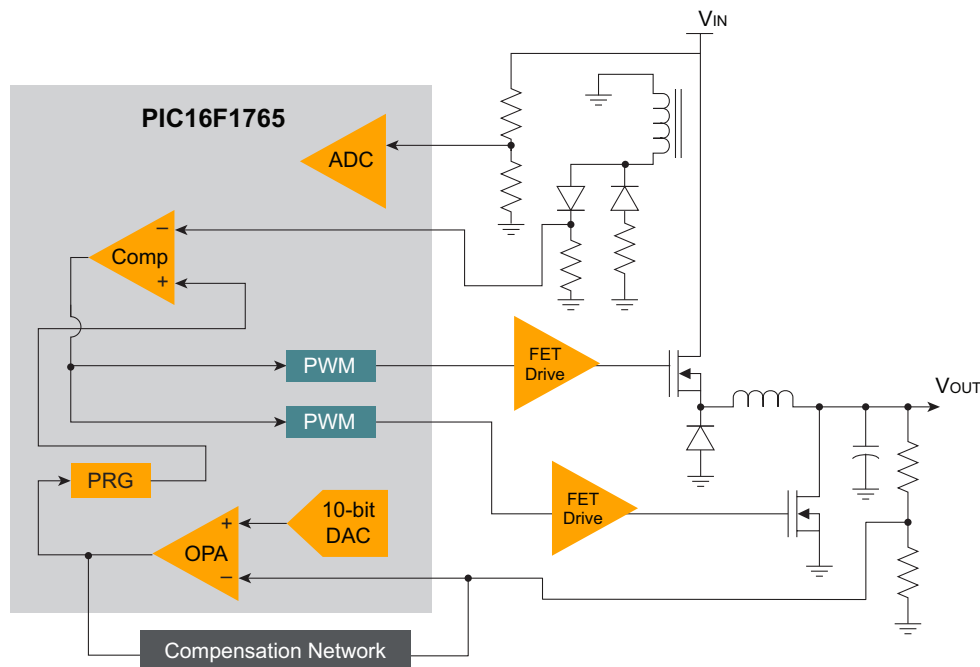
Full Digital Power

For the highest performance, dsPIC DSCs can close the control loop in the digital domain, with powerful algorithms to maximize efficiency at all load conditions. In applications where efficiency requirements are stringent, transient response is critical and monitoring/reporting are mandatory for maximum up-time, the benefits of a fully digital power supply are more than just added value, they are a competitive necessity. This approach is perfectly suited for multi-stage AC-DC or DC-DC conversions, renewable energy, server and computing applications.

Power Factor Correction (PFC) is essential in higher wattage power supplies to reduce harmonic content, system losses and radiated emissions. In the example below, the dsPIC DSC simplifies the implementation of a Boost-PFC algorithm using Average Current Mode Control. The current reference is calculated digitally by computing the product of rectified input voltage, the output of the voltage error compensator and the output of the voltage Feed-Forward. The digital PFC function uses few DSC resources, leaving plenty of additional capability to perform other functions.

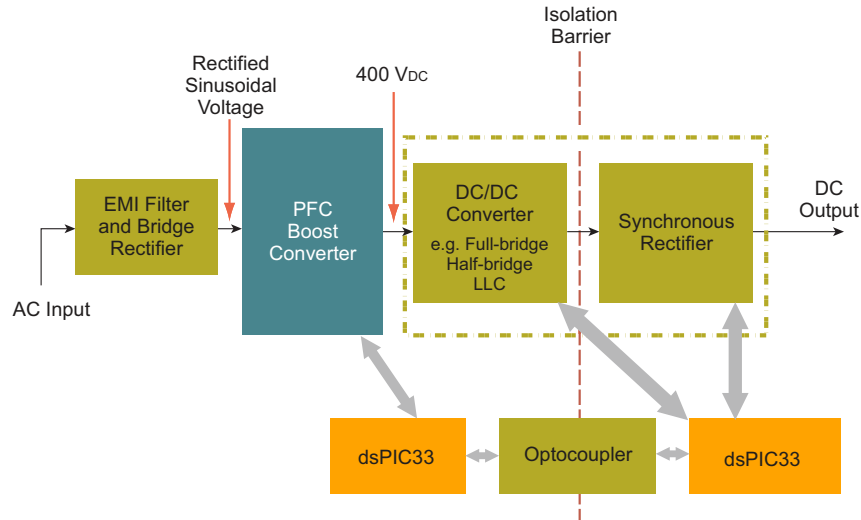### Semi-Bridgeless PFC with Advanced Digital Control
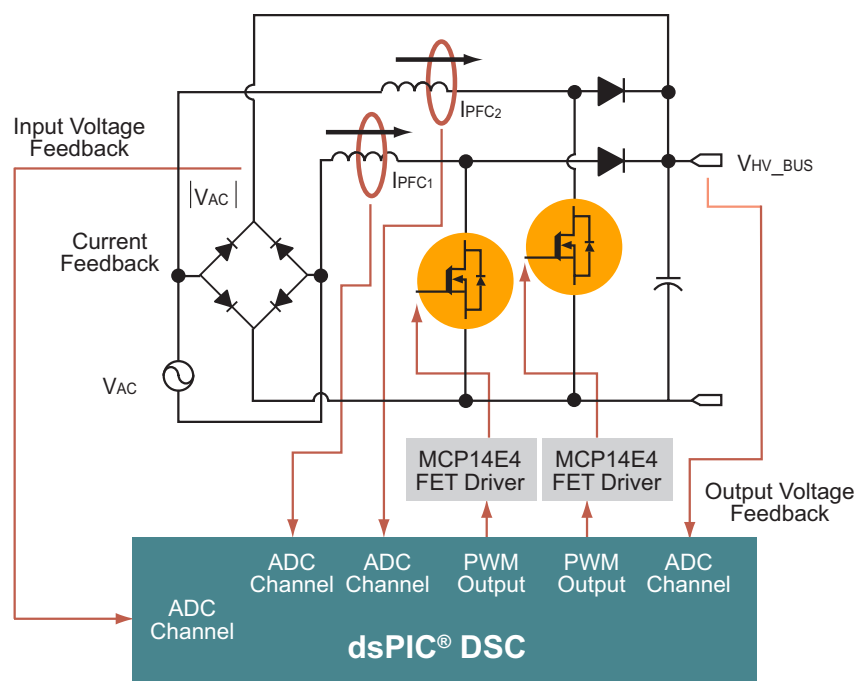
The features of the dsPIC DSCs enable full digital control of applications such as the AC-DC converter illustrated below. The high-speed PWM module provides many operating modes to facilitate implementing various advanced conversion topologies such as power factor correction (PFC), phase-shifted full-bridge with synchronous rectification, and multi-phase buck converters. High-speed ADC conversions can be triggered at precise times in relation to the PWM signal, supporting fast control loops. The high-performance CPU enables implementing advanced digital control loops and compensators in software.

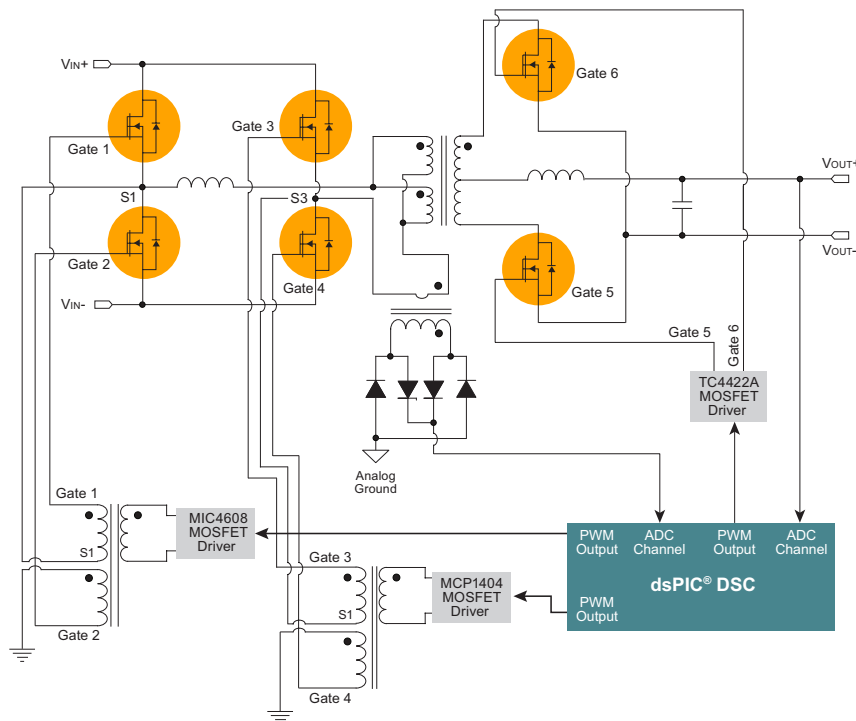The dsPIC33 DSC family dynamically controls different power stages in power-efficient and highly integrated DC-DC converters. The high-speed ADC, PWM and comparators work together requiring minimal CPU bandwidth. Faster digital control loops and compensators can be executed using a high-performance DSP engine. Advanced features such as dynamic load response, protections, sequencing and communications can also be implemented.

AC-DC Conversion with Complete Digital Control

Isolation Barrier

Rectified Sinusoidal Voltage

400 V_{DC}

EMI Filter and Bridge Rectifier

PFC Boost Converter

DC/DC Converter
e.g. Full-bridge Half-bridge LLC

Synchronous Rectifier

DC Output

AC Input

dsPIC33

Optocoupler

dsPIC33

Phase-Shifted Full-Bridge DC-DC Converter

$V_{IN}+$

Gate 6

Gate 1

Gate 3

$V_{OUT}+$

S1

S3

Gate 2

Gate 4

Gate 5

$V_{OUT}-$

$V_{IN}-$

Gate 5

Gate 6

TC4422A MOSFET Driver

Analog Ground

Gate 1

MIC4608 MOSFET Driver

Gate 3

MCP1404 MOSFET Driver

S1

S1

PWM Output

ADC Channel

PWM Output

ADC Channel

dsPIC® DSC

PWM Output

Gate 2

Gate 4

Digital Control of Analog Regulators

The 6-pin PIC10F family of devices and the 8-pin PIC12F devices allows digital features to be integrated into any power supply design with minimal BOM impact. These devices provide signal generation, custom logic and signal conditioning to augment analog power supply designs, providing on/off control, soft start, power sequencing or monitoring features to your application.

These devices include:
- Comparator
- Internal 8-bit ADC
- 10-bit PWMs
- Configurable Logic Cell (CLC)
- Complementary Waveform Generator (CWG)
- Numerically Controlled Oscillator (NCO)

Core Independent Peripheral (CIP) Hybrid Power Controllers

The 8-bit PIC16F devices are offered in 14-pin through 64-pin packages. These device families are suitable for proportion and configuration or topology control. Variants have multiple PWMs with peripherals that create complementary output waveforms, which can be used to drive analog control loops. Built-in op amps, ADCs and high-speed comparators can be used to create feedback loops for Peak Current Mode Control (PCMC) and temperature monitoring. The Programmable Ramp Generator and Slope Compensation peripherals automate and simplify output stabilization of Switch Mode Power Supplies. Highly integrated products feature peripheral support for up to four independent Switch Mode Power Supplies, with built-in LED dimming engine functionality. Specialized timers can be employed to monitor for fault conditions. The Configurable Logic Cell peripheral can be used to reconfigure feedback loops on the fly, as needed within the application.

The Core Independent Peripherals operate autonomously and can alter system performance, with little or no core intervention. This allows users to put the core to sleep, reducing power consumption. Communication peripherals can be used for remote monitoring and control. Key features of these microcontroller families are:
- 8-/10-/16-bit PWMs
- Complementary Output Generator (COG)/Complementary Waveform Generator (CWG)
- Op amps, high-speed comparators, 10-/12-bit ADCs, 5-/8-/9-bit DACs
- Slope Compensation (SC), Programmable Ramp Generator (PRG)
- Hardware Limit Timer (HLT), 24-bit Signal Measurement Timer (SMT), Zero Cross Detect (ZCD)
- Communication interfaces: EUSART, SPI, I²C

Select 8-bit PIC10F, PIC12F and PIC16F Microcontrollers

Product	Pins	Flash Memory (B)	Self Read/Write	RAM (B)	EE Bytes	Timer 8-/16-bit	PRG/SC	Op Amp	ZCD	Comparator	PWM	ADC	DAC	DSM	EUSART	SPI/I²C
PIC16F18313	10	3.5 K	✓	256	256	3/1	–	–	–	1	1 × Half Bridge	5 × 10-bit	1 × 5-bit	1	1	1
PIC16F(HV)753	14	3.5 K	✓	128	HEF*	3/1	0/1	–	–	2	1 × Half Bridge	8 × 10-bit	1 × 9-bit	–	–	–
PIC16F1765	14	14 K	✓	1 K	HEF*	4/3	1/0	1	1	2 × High Speed	1 × Full Bridge	8 × 10-bit	1 × 5-bit 1 × 9-bit	1	1	1
PIC16F1769	20	14 K	✓	1 K	HEF*	4/3	1/0	2	1	4 × High Speed	2 × Full Bridge	12 × 10-bit	2 × 5-bit 2 × 9-bit	2	1	1
PIC16F1778	28	28 K	✓	2 K	HEF*	4/3	1/0	3	1	6 × High Speed	3 × Full Bridge	17 × 10-bit	3 × 5-bit 3 × 9-bit	3	1	1
PIC16F1779	40	28 K	✓	2 K	HEF*	4/3	1/0	4	1	8 × High Speed	4 × Full Bridge	28 × 10-bit	4 × 5-bit 4 × 9-bit	4	1	1

*High-Endurance Flash: 128B non-volatile data storage with high-endurance 100k E/W cycles

Digitally Enhanced Power Analog (DEPA)

The Digitally Enhanced Power Analog Product Family mixes analog PWM control loops with supervisory microcontrollers. The PIC MCU core controls the operation of an analog compensation and amplifier based control loop; capable of on-the-fly adjustments to the analog reference, frequency, dead-time, compensation, fault behavior and almost every operating parameter of the power supply. These are an excellent choice if you want to design with traditional analog pole-zero compensation and control techniques, while adding digital interfacing and digital reconfigurability. These devices feature:

- Integrated LDOs for high input voltage operation (up to 42V)

- Integrated MOSFET drivers for control of large power MOSFETs (can drive 30A MOSFETs)
- Integrated 10-bit ADC for feeding valuable analog system information into the MCU core
- Integrated mid-range PIC MCU core
- 2 × 3 DFN , 6-pin SOT-23 packages
- Comparator
- Internal 8-bit ADC
- 10-bit PWMs
- Configurable Logic Cell (CLC)
- Complementary Waveform Generator (CWG)
- Numerically Controlled Oscillator (NCO)

Digitally Enhanced Power Analog (DEPA) Controllers

Product	Min. Operation Voltage (V)	Max. Operation Voltage (V)	Package Size (mm)
MCP19114	4.5	42	4x4
MCP19116	4.5	42	4x4
MCP19124	4.5	42	4x4
MCP19118	4.5	40	4x4
MCP19122	4.5	40	4x4
MCP19110	4.5	32	4x4
MCP19115	4.5	42	5x5

| Product	Min. Operation Voltage (V)	Max. Operation Voltage (V)	Package Size (mm)
MCP19117	4.5	42	5x5
MCP19125	4.5	42	5x5
MCP19114	4.5	42	5x5
MCP19215	4.5	42	5x5
MCP19119	4.5	40	5x5
MCP19123	4.5	40	5x5
MCP19111	4.5	32	5x5

Development Boards

MCP19111 PMBus Enabled Point of Load (POL) Demonstration Board (ARD00609)

This board demonstrates how the MCP19111 device operates as a PMBus-enabled POL converter over a wide input voltage and load range. The firmware is preloaded in the MCP19111, so no software development is needed. A USB-to-PMBus bridge is included, allowing direct communication with a PC using a PICkit In-Circuit Debugger/

Programmer. Nearly all operational and control system parameters are programmable and readable via the PMBus. A full-featured and easy-to-use GUI can be downloaded from the Microchip website or you can program the MCP19111 using your own firmware, tailoring it to you application. This board contains headers for In-Circuit Serial Programming™ (ICSP™), I²C/PMBus communication and a mini USB connector.

MIC45208-1YMPL Evaluation Board (MIC45208-1YMP-EV)
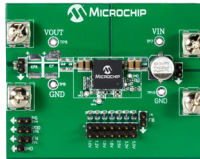
The MIC45208 is a synchronous step-down regulator module, featuring a unique adaptive ON-time control architecture. The module incorporates a DC-to-DC controller, power MOSFETs, bootstrap diode, bootstrap capacitor and an inductor in a single package, simplifying the design and layout process. The module accepts a 4.5V to 26V input, generates a 0.8V to 5V output up to 10A and features an adjustable switching frequency.

Select Analog Portfolio for Power Applications

Product Line	Example Devices	Description
Power Modules	MIC45205, MIC45212, MIC3153	Integrated buck converters, system-in-package including an integrated inductor for the simplest, lowest-noise, easiest-to-implement power conversion solutions.
LDOs	MCP1703A, MIC528X, MIC5265, MIC5504, MIC2930X	Power your digital controller from your input rail for clean startup and intelligent control under the widest possible range of input conditions. Low quiescent current, high output current, high input voltage linear regulators offer clean, low noise, easy-to-implement controller power.
Switching Regulators	MIC2199, MIC2290, MIC28512, MCP16331, MIC24046, MIC2605, MCP16251, MCP1642	Switching regulators with enable functions to allow the intelligent power controller to disable subsystems when needed.
MOSFET Drivers	MCP14A015X, MCP1403/4/5, MIC5021, MIC4608, MCP14700, MIC4605	Low-side, high-side, half-bridge and full-bridge drivers for interfacing low-voltage digital PWM outputs to high-voltage, large-capacitance power MOSFETs; some include shoot-through and other protection features.
Operational Amplifiers	MCP629X, MCP6H9X, MCP600X, MIC6211	High-speed, high-voltage amplifiers scale and condition analog feedback signals for input to a digital controller.
Load Switches	MIC2025, MIC94063, MIC2026, MIC2544	Load switches allow management and sequencing of power to sub-systems, intelligently responding to environmental factors monitored by the intelligent power supply controller.
Temperature Sensors	MCP9800/4, MCP9509, MCP9700	Temperature sensors provide high-accuracy, local temperature measurement and over-temperature warnings with a variety of interface outputs for communicating with digital controllers.
PWM Controllers	MCP19035, MCP1632, MIC2125/6, MIC2103/4	PWM controllers with external inputs to control frequency, output voltage, current limit or other operating parameters from pin-connected passive devices or a supervisory MCU.

dsPIC DSCs with Advanced Peripherals for Digital Power Control

Implementing advanced software digital control loops for power applications requires a high-performance DSP engine along with specialized peripherals. The high-performance CPU and rich peripherals of dsPIC DSCs enable solutions with minimal external support requirements. In addition to their space and cost-saving benefits, dsPIC DSCs solutions offer special features that enable advanced power conversion designs. The DSP engine can perform single-cycle MAC with up to 40 bits of resolution, data saturation, zero overhead looping and barrel shifting to support fast control loop execution. These devices contain peripherals specifically designed for power conversion. Peripherals such as high-speed PWM generators, ADCs and analog comparators can be tied together using an internal configurable control fabric that enables them to interact directly with one another, resulting in stunning performance gains in digital power applications.

- Large family of code- and pin-compatible Flash devices
- Up to 100 MIPS 16-bit CPU with compiler-efficient architecture
- Built-in DSP engine enables high-speed, high-precision digital power control loops
- 40-bit accumulators
- Precision high-speed internal oscillators do not require external crystal oscillator components

- Comprehensive system integration features

Advanced On-chip Intelligent Power Peripherals Microchip's 16-bit dsPIC DSCs provide on-chip peripherals specifically designed for high-performance, intelligent power supplies:

- Power Supply PWM Module (High-speed PWM Module)
  - Up to 250 pico-second resolution
  - Highly configurable supporting all common topologies
  - High resolution at high PWM frequencies
  - Trigger events from PWM to ADC
- High-speed ADC
  - Up to 12-bit resolution
  - Up to 3.5 Msps
  - Sophisticated triggering capabilities
- High-speed analog comparator
  - Up to four analog comparators
  - Up to four integrated 12-bit DAC references
  - Outputs can directly trigger PWM and ADC events
- Additional channels of 16-bit timers, input capture, circuits, output comparators and PWM generators
- Communications include UART, SPI, I²C, PMBus™ and CAN/CAN-FD interfaces

www.microchip.com/power

Which MCU or DSC Should You Choose?

Select dsPIC33 SMPS and Digital Power Conversion Family

Product	Pins	Flash (KB)	RAM (Bytes)	IC/OC	PS PWM	ADC	PGAs*	Analog Comparator	UART/ I²C/SPI	CAN**
dsPIC33EPXXXGS70X/80X	28-80	64-128	8 K	4/4	8X2	(17-22) × 12-bit, 5 S/H	2	4	2/2/3	0-2
dsPIC33EPXXGS50X	28-64	16-64	2 K -8 K	4/4	5X2	(12-22) × 12-bit, 5 S/H	2	4	2/2/2	0
dsPIC33EPXXGS202	28	16-32	2 K	1/1	3X2	12 X 12-bit, 3 S/H	2	2	1/1/1	0
dsPIC33CH128MPX0X	28-80	64- 128 (Master)/ 24 (Slave)	16 K (Master)/4 K (Slave)	12/12	4X2 Master 8X2 Slave	(23-34) X 12-bit, 4 S/H	3	4	3/3/3	0-1
dsPIC33CH512MPX0X	48-80	256- 512 (Master)/72 (Slave)	32-48 K (Master)/ 16 K (Slave)	12/12	4X2 Master 8X2 Slave	(31-34) X 12-bit, 4 S/H	3	4	3/3/3	0-2
dsPIC33CK256MPX0X	28-80	32-256	8 K-24 K	9/9	(4-8)X2	(12-24) X 12-bit, 3 S/H	2-3	3	3/3/3	0-1
dsPIC33CK64MP105	28-48	32-64	8 K	5/5	4X2	(12-19) X 12-bit, 3 S/H	2-3	3	3/2/3	0

*PGAs: Programmable Gain Amplifiers. The CH family of devices have PGAs, whereas the CK family of devices have OpAmps   **C Family devices have CAN-FD

Development Boards

dsPIC33C Digital Power Starter Kit (DM330017-3)

The starter kit is intended to introduce and demonstrate the capabilities and features of Microchip's latest dsPIC33C family of devices targeted for digital power applications. The dsPIC33C Digital Power Starter Kit features on-board dsPIC33CK256MP505 single-core DSC, SMPS power stages, loads, LCD display, USB/UART bridge and programmer/debugger, which eliminates the need for any additional hardware.

MPLAB® Starter Kit for Digital Power (DM330017-2)

This kit uses the dsPIC33EP64GS502 DSC to implement a buck converter and a boost converter. Each converter can drive its on-board MOSFET controlled resistive load or an external load. The board has an LCD display for voltage, current, temperature and fault conditions, and an integrated programmer/debugger, all powered by the included 9V power supply.

Low Voltage PFC Development Kit (DV330101)

Low Voltage Power Factor Correction (LVPFC) Development Kit offers safe voltage levels at moderate power while designing algorithms on a boost power factor correction topology. These algorithms can be applied on real systems under development with minimal changes. The LVPFC Development Board utilizes the dsPIC33EP128GS806 device, supporting full digital and advanced power control algorithm schemes.

Digital Power Development Board (DM330029)

The Digital Power Development Board is a demonstration board that offers a flexible measurement and evaluation platform for all compatible Microchip dsPIC33's Digital Power Plug-In Modules (DP PIMs). The DP PIMs can be inserted into the mating socket in the middle of the Digital Power Development Board. All pins of the DP PIM are accessible via test loops or pin headers.

Digital Power Plug-In Modules (DP PIMs)
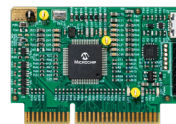
Microchip's DP PIMs feature different device families, from dsPIC33E to dsPIC33CK and dsPIC33CH DSCs. These devices have different CPU performance levels as well as peripheral features and functions. These DP PIMs have the same functional card edge connector pinout to support seamless migration between device families. The DP PIMs plug into a range of digital power development boards and reference designs.

dsPIC33EP128GS808 Development Board (DM330026)
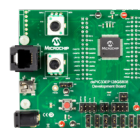
The dsPIC33EP128GS808 Development Board allows users to evaluate the features of dsPIC33EP 'GS' series devices. The dsPIC33EP 'GS' devices offer new peripherals and features that can be explored using the development board. Configurable connectors make it easy to connect different peripherals together to test features that would otherwise require additional hardware. The development board can also be used to develop dual CAN communication systems when used along with the CAN/LIN/J2602 PICtail™ (Plus) Daughter Board.

Microchip's Intelligent power reference designs enable optimized system development and faster time to market. To request an evaluation kit for any of these reference designs, please contact your local Microchip FSE/FAE.
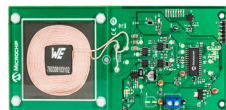
Wireless Power

Our dsPIC Digital Signal Controllers, with their multiple Pulse-Width Modulators (PWMs), high-speed Analog-to-Digital Converters (ADCs) and programmable core, are very effective in optimizing wireless charging solutions. To help jump start your development, Microchip offers reference designs for 15W single- and multi-coil Qi compliant transmitters.

For applications that may require higher wattage, we also offer the 200W/300W Wireless Power reference design, implementing a proprietary protocol, which is ideal for applications such as power tools, vacuum robots, industrial slip rings, small electric vehicles and drones.

15W Single-Coil Wireless Power Transmitter Reference Design

The 15W Wireless Power Transmitter, based on the dsPIC DSC, is compatible with Qi medium power receivers. The development board enables a system efficiency of about 80% at full load and includes status LEDs and LEDs for power level indication and operates at an efficiency of 80% at 15W of power.

### 15W Three-Coil Wireless Power Transmitter Reference Design
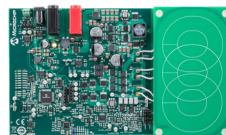
The Three-Coil Transmitter is based on a fixed frequency variable voltage control topology. The transmitter is based on a dsPIC33C Core CPU core with high-speed ADCs/PGAs, multiple PWMs provides the required flexibility to optimize the Transmitter performance. The Front-End Buck-Boost converter required for the variable voltage topology is controlled by the dsPIC DSC. The reference design includes Q-Factor and power-loss foreign object detection. The CAN functionality enables seamless integration into the Automotive environment. The dual-core dsPIC enables partitioning of functionality effectively. This reference design facilitates designing a Qi compliant solution.

200W/300W Wireless Power Reference Design

The 200W/300W Wireless Power reference design implements a proprietary protocol developed from several years of R&D and granted U.S patents in the field of wireless power. The 200W/300W solution is ideal for applications such as power tools, vacuum robots, industrial slip rings, small electric vehicles and drones.

AC-to-DC Power Supplies
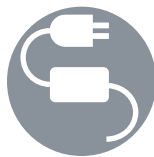
AC-DC switch mode power supplies are designed to provide DC power from AC line voltages. The reference designs below include information on Power Factor Correction, high voltage compatible bias generation and primary/secondary isolation. In addition, these reference designs also include a microcontroller for control, monitoring, communications and intelligent automated functions.

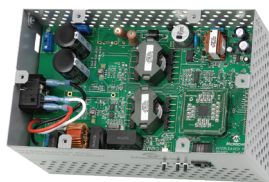### 750W AC/DC Reference Design

Microchip's 750W AC-DC Reference Design demonstrates a semi-bridgeless PFC topology followed by a peak current controlled zero-voltage switching full-bridge (ZVS FB) converter with digital slope compensation to achieve very high conversion efficiencies. This power supply can be firmware updated (including the compensator algorithm) with zero down time to the system it is powering while the power supply is running. It is implemented using two dsPIC33EP "GS" digital-power DSCs that provide full digital control of the power conversion as well as all system management functions.

Platinum-Rated 720W AC/DC Reference Design

Demonstrating the flexibility of dsPIC DSCs in Switch ModePower Supplies (SMPS), this reference design has a peak efficiency of 94.1% and achieves the ENERGY STAR® CSCI Platinum Level. It features a 2-phase interleaved power factor correction boost converter followed by a 2-phase interleaved two-switch forward converter with synchronous rectification.

Digital Power Interleaved PFC Reference Design

This reference design provides an easy method to evaluate the power and features of the SMPS dsPIC DSCs for IPFC applications. It features a universal input voltage range and produces a single high-voltage DC output up to 350W with low Total Harmonic Distortion (THD) of the input current.

Vienna 3-Phase Power Factor Correction (PFC) Reference Design (SICPFC/REF5)

The MSCSICPFC/REF5 is a 3-phase Vienna PFC reference design for Hybrid Electric Vehicle/ Electric Vehicle (HEV/EV) charger and high-power switch mode power supply applications. This reference design achieves 98.5% efficiency at 20 kW output power and is capable of operating up to 30 kW. The reference design showcases the dsPIC33CH dual-core digital signal controller, implementing digital control, and the next-generation 1200V Silicon Carbide IC (SiC) diodes and 700V SiC MOSFETs with high avalanche/repetitive Unclamped Inductive Switching (UIS).

DC-to-DC Power Supplies
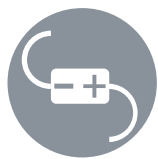
Power Conversion using switch mode power supply design is typically more efficient than linear regulation. These reference designs provide examples of switching converters with built in microcontrollers. The microcontrollers provide management functions as well as the controller functions required for the switch mode power conversion.

200W DC/DC LLC Resonant Converter Reference Design

A single dsPIC33EP "GS" digital power DSC provide full digital control of the power conversion and system management functions in this reference design. It operates over a wide input voltage range (350–420V DC) with a nominal input of 400V, providing a 12V DC output while maintaining high-voltage isolation between the primary and secondary.

Quarter Brick DC/DC Converter Reference Design
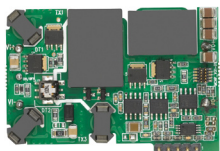
This reference design provides an easy method to evaluate the performance and features of SMPS DSCs in high-density quarter brick DC-DC converters.

Battery Management

Every battery type has its own unique charging requirements. Managing these diverse requirements, while cell-balancing, fuel-gauging and managing power paths, becomes very complex. Flyback, buck, and boost topology design examples using PIC MCUs and dsPIC DSCs can handle these functions in compact, easy to implement circuits. The designs include temperature, voltage, current, and time monitoring. In addition, the charge profiles can be customized in firmware to match the exact requirements of a battery manufacturer, and to allow any desired customization to improve battery capacity, charge time, or system lifetime.

MCP19111 Battery Charger Evaluation Board (ADM00513)
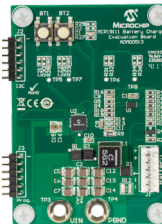
The MCP19111 Battery Charger Evaluation Board demonstrates the features of a programmable and configurable multi-chemistry battery charger.The MCP19111 can be programmed to make a very flexible battery charger by controlling a high efficiency synchronous buck circuit. The controller dynamically moves from voltage to current controlled charging, following the charge characteristics of the target battery chemistry, and the operation can be adjusted or monitored using the available software GUI, a PICkit™ Debugger and a USB connection.

Digital Lighting Control

Binning, temperature, component aging, dimming and constant current-drive needs influence light quality – affecting the customer experience. In addition to efficiency benefits or lifetime monetary savings, consumers are looking for better interior designs, brighter headlights, more beautiful colors and finer dimming control. To make better LED and traditional lighting circuits, for proper color, temperature and chromaticity, start with a Microchip evaluation board or reference design. These designs can be implemented as stand-alone systems using a traditional dimmer and AC input; or as connected systems supporting standard or custom communication protocols to open new control possibilities.

### MCP19215 Dual Boost/SEPIC Evaluation Board (ADM00799)
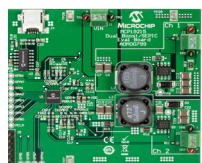
This board demonstrates how the MCP19215 device operates in Boost and SEPIC topologies over a wide input voltage and load range. Nearly all operational and control system parameters are programmable by utilizing the integrated PIC microcontroller.

MCP19114 Flyback Standalone Evaluation Board (ADM00578)
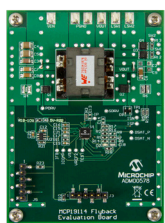
The MCP19114-Flyback Standalone Evaluation Board and Graphical User Interface (GUI) demonstrate the MCP19114 performance in a synchronous Flyback topology. It is configured to regulate load current, and is well suited to drive LED loads. Nearly all operational and control system parameters are programmable through the integrated PIC MCU core. The MCP19114 evaluation board comes preprogrammed with firmware designed to operate with the GUI interface.

SMPS Solar Power
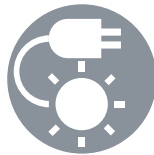
Solar related power conversion is becoming more important with increase in solar power adoption and stringent efficiency requirements. Microchip's grid-connected solar micro inverter reference design, with the dsPIC DSC, has a maximum power output of 215W and provides a high efficiency of ~94% at nominal conditions (230V AC). Microchip also has a portable solar charging reference design based on a PIC16F MCU that can charge a 24V battery system from a 130W/12V solar panel. This design can provide 1.3 kWh of energy in 10 hours of charging time.

Grid-Connected Solar Microinverter Reference Design

Demonstrating the flexibility and power of SMPS dsPIC DSCs in grid-connected solar microinverter systems, this reference design has a maximum output power of 215W and ensures maximum power point tracking for PV panel voltages between 20V to 45V DC. High efficiency is achieved by implementing a novel interleaved active-clamp flyback topology with Zero Voltage Switching (ZVS).

DC-to-AC Power Inverter

Microchip's UPS reference design includes a battery charger and a dsPIC based inverter which converts a 380V D.C battery voltage into a 220V A.C supply. Multiple PWMs, multiple ADC channels and a programmablen core in the dsPIC33FJ16GS504 device enable the optimization of the inverter design.
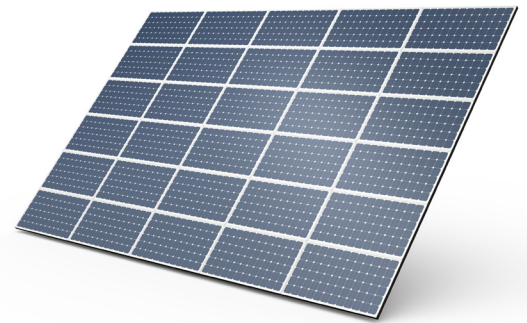
Digital Pure Sine Wave Uniterruptile Power Supply (UPS) Reference Design
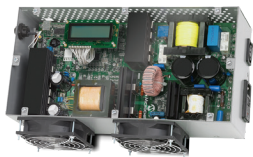
Implemented using a single dsPIC33F "GS" digital-power DSC, this reference design demonstrates how digital power techniques can be applied to UPS applications to reduce audible and electrical noise via a purer sine-wave output. It also shows how these techniques enable easy modification through software, the use of smaller magnetics, the creation of higher-efficiency and compact designs, and a low bill-of-materials cost.

USB Power Delivery

Microchip's USB–C™ Power Deliver (PD) Reference Design is a two channel PD source side design intended for automotive applications. Each port can source up to 60W of power. The reference design features the dsPIC33CK single-core DSC, implementing SMPS control of up to four software Buck Boost converters. The design specification includes an Input voltage range of 9 to 18V, and a maximum charging current of 3A.

Digital Compensator Design Tool (DCDT)

Use this free MPLAB X IDE plug-in to calculate optimum compensator coefficients for maximum performance, with support for five common compensator types. It can also be used to analyze system response as well as stability.

SMPS Compensator Library

This library contains optimized functions for the dsPIC33 family of DSCs implementing common compensator algorithms such as 2P2Z, 3P3Z and PID. These library functions are designed to be used within an application framework, offering an efficient and flexible way of implementing the control of an SMPS application.

The above tools can be downloaded from www.microchip.com/DPDS.

Microchip's Digital Power Design Suite

Microchip's Digital Power Design Suite includes the Digital Compensation Design Tool (DCDT), MPLAB Code Configurator (MCC), SMPS Compensator Libraries and design examples. The design suite offers tools and required guidance for developing complete digital power designs.

Digital Compensator Design Tool (DCDT)

The Digital Compensator Design Tool (DCDT) helps power supply designers by simplifying the compensator coefficients calculations and analyzing the control system performance. This topology independent GUI for designing complex compensators offers advantages like:

- Analyzing plant and feedback transfer functions
- Designing controller (PID, 2P2Z, 3P3Z, etc.)
- Migrating analog Type II, Type III to digital control
- Analyzing loop gain
- Tuning controller and normalizing coefficients
- Generating controller coefficients and exporting them to an MPLAB X IDE project

Design Examples and Reference Designs

Royalty-free application-specific hardware and software designs to reduce time to market:

- Starter kits, development/evaluation boards
- Reference designs and code examples
- Application notes

Hardware
- Powertrain
- Feedback
- dsPIC33 Controller

Firmware

| Digital Compensator Design Tool | MPLAB® Code Configurator | Microchip Compensator Libraries | Microchip Example Code |

Digital Compensator Design Tool — DCDT

MPLAB® Code Configurator — MCC

Working Design Examples — Examples

Compensator Libraries — LIB
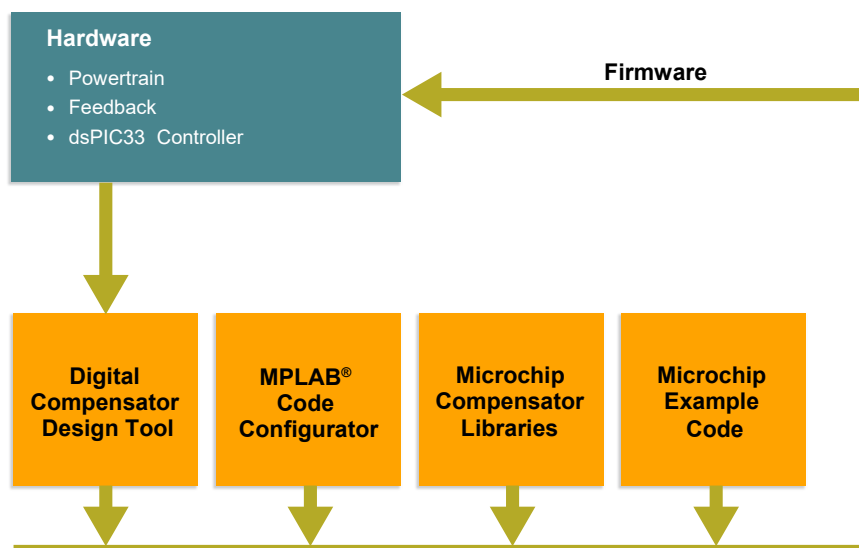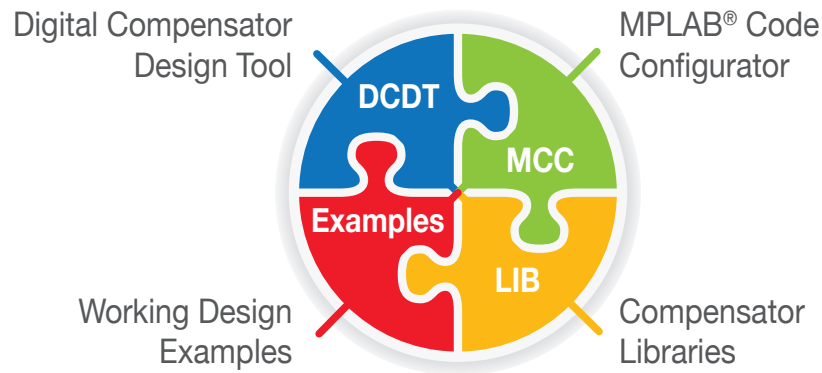
SMPS Compensator Library

The Compensator library includes optimized functions for the dsPIC33 DSCs that facilitate implementing common compensator algorithms and realize an efficient SMPS application design. The library supports:

- Algorithms like PID, 2P2Z, 3P3Z
- Fixed point
- Trigger update
- Context registers on 'GS' and 'MP' family devices

MPLAB Code Configurator

MCC is a graphical programming environment that generates seamless, easy-to-understand device configuration code. It offers advantages like:

- Intuitive interface for quick start
- Automatic configuration of peripherals
- Reduces overall design effort
- Minimizes references to product datasheet

Simplified SMPS Design Flow

1. Abstract the plant
   - Simulation environment – MAT LAB / SIMPLIS
   - Small signal modelling
   - Measurement using frequency analyzer
2. Use DCDT to:
   - Analyze plant & feedback transfer function
   - Generate compensator coefficients
3. Use MCC to generate device initialization code
4. Create final firmware with the help of example codes and reference designs

Intelligent Power Supply Training and Resources

Making Your Power Applications Intelligent The Easy Way!

Log on to www.microchip.com/power and navigate to the "Documentation->Webinars" tab at the bottom of the page to find intelligent power training.

Web Seminar Title	Language	Duration
Quarter Brick Phase Shifted Full Bridge DC/DC Converter	English	20 min
LLC Resonant Converter Reference Design Using the dsPIC® DSC	English	20 min
Microchip's Grid Connected Solar Microinverter Reference Design	English	14 min
Controlling High Brightness LEDs using the dsPIC DSC	English	12 min
Control System Design for Power Converters	English	21 min
Switch Mode Power Supply Topologies – The Forward Converter	English	26 min
SMPS Topologies – The Buck Converter	English	24 min
Switch Mode Power Supplies (SMPS) Part 1	Japanese	23 min
Introduction to Switch Mode Power Supplies (SMPS)	English	25 min
SMPS Components and Their Effects on System Design	English	31 min
SMPS Buck Converter Design Example	English	12 min
Introduction to SMPS Control Techniques	English	22 min
Advanced SMPS Topics	English	20 min
Introduction to the dsPIC DSC SMPS (Part 1)	English	20 min
Introduction to the dsPIC DSC SMPS (Part 2)	English	25 min
Building a dsPIC DSC SMPS System	English	10 min
Designing Intelligent Power Supplies	English	30 min
Developing Intelligent Power Systems Using the MCP1630 High-Speed PWM	English	20 min
Lithium-Ion Battery Charging: Techniques and Trade-offs	English	20 min
Offline UPS Reference Design Using the dsPIC DSC	English	30 min

Need Design Assistance?

Visit www.microchip.com/partners for a directory of third-party consultants and designers that can help with your intelligent power solutions design.

Intelligent Power Solution Application Notes/User Manuals/Software

Intelligent Power Solution Application	Document	Description
AC-DC	AN701	Switch Mode Battery Eliminator Based on a PIC16C72A
	AN954	Transformerless Power Supplies: Resistive and Capacitive
	AN1106	Power Factor Correction in Power Conversion Applications Using dsPIC® DSCs
	AN1278	Digital Power IPFC Reference Design
	DS00070320	SMPS AC/DC Reference Design User's Guide
	AN1421	Platinum-Rated AC/DC Reference Design Using the dsPIC DSC
DC-DC and POL	AN216	DC/DC Converter Controller Using a PIC® Microcontroller
	AN874	Buck Configuration High-Power LED Driver
	AN1025	Converting a 5.0V Supply Rail to a Regulated 3.0V
	AN1086	Switching Power Supply Design with the PIC16F785
	AN1335	Phase Shifted Full Bridge Quarter Brick DC/DC Converter Reference Design
	AN1336	LLC Resonant Converter Reference Design
	DS00070181	dsPICDEM™ SMPS Buck Development Board User's Guide
	DS00070336	Buck/Boost Converter PICtail™ Plus Daughter Board User's Guide
	TB053	Generating High Voltage Using the PIC16C781/782
	TB081	Soft-Start Controller for Switching Power Supplies
	TB085	A Simple Circuit for Driving Microcontroller Friendly PWM Generators
	AN2388	Peak Current Controlled ZVS Full-Bridge Converter with Digital Slope Compensation
	AN1369	Full-Bridge Quarter Brick DC/DC Converter Reference Design Using a dsPIC DSC
	AN1477	Digital Compensator Design for LLC Resonant Converter
	AN1495	Average Current Mode Control of LLC Resonant Converter
Battery Management	AN626	Lead Acid Battery Charger using the PIC14C000
	AN667	Smart Battery Charger with SMBus Interface
	AN947	Power Management in Portable Applications: Charging Lithium-Ion/Lithium-Polymer Batteries
	AN960	New Components and Design Methods Bring Intelligence to Battery Charger Applications
	AN1012	PIC16HV785: Programmable Lithium and Nickel Battery Charger
	AN1015	PIC16HV785: Programmable Lead Acid Battery Charger
Ignition Control	AN1980	Capacitor Discharge Ignition Using the Angular Timer
	AN2095	Transistor Coil Ignition with Integrated Remote Keyless Entry and Immobilizer Using PIC Microcontrollers
Solar Inverter	AN1338	Solar Micro Inverter Reference Design
General	AN538	Using PWM to Generate Analog Output
	AN1035	Designing with HV Microcontrollers
	AN1114	Switch Mode Power Supply (SMPS) Topologies (Part I)
	AN1207	Switch Mode Power Supply (SMPS) Topologies (Part II)
	AN1279	Offline UPS Reference Design Using the dsPIC DSC
	DS00001146	Compiled Tips 'N Tricks Booklet
	DS00021913	Power Solutions Design Guide
	DS00001036	Lighting Applications Design Guide
	CEXXXX	Code Examples For Various Peripheral and Digital Power Control Loops and Techniques
	DS50002330B	Digital Power Starter Kit Users Guide
	DS50002832A	Low Voltage PFC Development Kit Users guide

Getting Started

The Microchip website (www.microchip.com) provides a wealth of information that can help you get started with your intelligent power design.

Development Tools

Visit www.microchip.com/tools to learn more about all of Microchip's software and hardware development tools.

Intelligent Power Supply Design Center

If you would like more information about any of the solutions presented here, please visit the Microchip Intelligent Power Supply Design Center (www.microchip.com/power) for further details. The Design Center contains links to application notes, web seminars, user manuals and software referenced in this brochure.

Support

Microchip is committed to supporting its customers in developing products faster and more efficiently. We maintain a worldwide network of field applications engineers and technical support ready to provide product and system assistance. For more information, please visit www.microchip.com:

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- Knowledge base and peer help: www.microchip.com/forums
- Sales and Global Distribution: www.microchip.com/sales

Training

If additional training interests you, Microchip offers several resources including in-depth technical training and reference material, self-paced tutorials and significant online resources.

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- MASTERs Conferences: www.microchip.com/masters
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