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 designers 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
- 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 its 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
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.

<table>
<thead>
<tr>
<th>Description</th>
<th>Technical Functions</th>
<th>Recommended Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1: On/Off Control</td>
<td>Low-power standby&lt;br&gt;Programmable soft start&lt;br&gt;Power up sequencing&lt;br&gt;Primary/secondary communication bridge</td>
<td>PIC10F&lt;br&gt;PIC12F&lt;br&gt;MIC45408 Integrated Power Module&lt;br&gt;MIC28304 Integrated Power Module&lt;br&gt;MCP16XXX Integrated Switching Regulators</td>
</tr>
<tr>
<td>Level 2: Proportional Control</td>
<td>Output voltage margining&lt;br&gt;Load sharing and balancing&lt;br&gt;History logging&lt;br&gt;Primary/secondary communication bridge</td>
<td>PIC12F&lt;br&gt;PIC16F&lt;br&gt;PIC18F&lt;br&gt;PIC24F&lt;br&gt;MIC1631 PWM Controller&lt;br&gt;MIC2125 PWM Controller</td>
</tr>
<tr>
<td>Level 3: Topology Control</td>
<td>Optimize control loop for load changes&lt;br&gt;Enable common platform for multiple applications&lt;br&gt;Operational flexibility for different power levels</td>
<td>PIC16HV785&lt;br&gt;PIC18F&lt;br&gt;MCP19115&lt;br&gt;MCP19119</td>
</tr>
<tr>
<td>Level 4: Full Digital Control</td>
<td>Dynamic control loop adjustment&lt;br&gt;Predictive control loop algorithms&lt;br&gt;Operational flexibility for different power levels</td>
<td>dsPIC33E&lt;br&gt;dsPIC33F</td>
</tr>
</tbody>
</table>
Power Supply Design Integration Levels

Level 1 Integration: On/Off Control
At Level 1, electronic intelligence augments a standard analog design. The intelligence provides limited on/off control functions such as start-up sequencing, automatic shutdown and watchdog fault detection functions. These manage analog PWM controllers or integrated regulators, such as the MIC2125 controller or the MIC45208 power module. At a basic level, the MCU can switch enable pins and read power good signals from the analog power controllers. More sophisticated solutions can provide logging functions for later failure analysis, remote communication and customized thermal control algorithms. Level 1 intelligence helps you ensure that the power supply has a deterministic response to system fault events. Solutions at this level benefit from Microchip's baseline and mid-range MCUs and analog products.

It is easy to make your existing analog power supply intelligent with minimal hardware modifications and few software changes. Microchip's PIC10F and PIC12F 8-bit low-pin-count and small-package microcontrollers with built-in peripherals—such as ADC, PWM and GPIOs—add intelligence to existing analog power supplies by controlling the output sequencing and monitoring of input/output voltage, current and temperature.

Simple Control and Monitoring

A Level 2 control system has much greater integration with the power supply and allows greater power supply environment monitoring. An ADC is used to monitor the power supply inputs and outputs. On-chip comparators can also be employed to ensure fast response to system events or faults. A PWM peripheral provides direct control of the analog PWM circuitry of the power unit. The PWM control can be used to gate the analog power supply under power-up conditions to provide soft start. The MCU can monitor the power supply input current during the soft start to ensure that components are not over stressed. Serial communication peripherals allow coordination from a host device; control and monitoring of cooling fans; and monitoring of temperature sensors.

Digital Monitoring to Analog Power Supply

Level 2 Integration: Proportional Control
This integration level delivers additional digital control to the standard analog design. Supplementing existing Level 1 control features, this level integration enables the control of output voltage, voltage limits, current limits and thermal limits. Most of the operating parameters of the analog power supply can be digitally controlled and monitored. Different soft-start profiles and current limits can be programmed to suit the application. The output voltage can be fine tuned to provide coordination between multiple power supplies in a system. Depending on the system I/O requirements, 8-bit solutions in the PIC12, PIC16 or PIC18 device families can provide the ideal control solution. In larger systems, the 16-bit PIC24 device family can provide more communication peripherals. These need to be matched to flexible analog PWM controllers in order to manipulate the PWM operation. Devices like the MCP1631 or MIC2155 with external frequency synchronization, external reference and similar external controllable inputs allow for more manipulations by the PIC microcontrollers.
Level 3 Integration: Topology Control

In addition to Level 1 and Level 2 features, this level permits the standard analog design to be reconfigured. Changing the analog loop configuration and swapping between multiple analog control loop filters can be achieved in the configurable, digital portion of the design. For example, a power supply can change from a PWM control loop to a hysteretic control loop at light loads. This change would allow a continuous inductor current design to operate in discontinuous conduction mode, under selected conditions, increasing system efficiency. On-the-fly switching frequency adjustments can also minimize losses. Microchip’s entire range of MCUs and DSCs can assist in Level 3 control applications. In particular, mixed-signal solutions such as the PIC16F176X and PIC16F177X product families are well-suited for topology control of up to four independent power supply channels. These families integrate an MCU with Intelligent Analog and Core Independent Peripherals (CIPs) that can be interconnected, creating feedback loops which drive and control Switch Mode Power Supplies (SMPS). In addition, the MCP1630 and MCP1631 PWM controllers are designed for MCU power controller applications. Alternatively, Microchip’s Digitally-Enhanced Power Analog controllers (MCP19XXX) combine a finely tuned analog control loop and supervisory microcontroller into a single device.

Precision LED Dimming Engine Application

As an example, the PIC16F1765 can be used in a Level 3 application due to the on-chip Core Independent Peripherals and Intelligent Analog. The peripherals perform functions autonomously within minimal core intervention and can alter system performance for faster response time, freeing the core to perform other tasks. The topology can be controlled via registers for the peripherals on the fly, to change between Buck, Pass Thru and Boost regulators based on feedback from the input voltage, output voltage or current.

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.
Moving to a Higher Level: Level 4 Full Digital Control

Full digital control replaces the standard analog control loop design and also provides the power management functions of Levels 1-3 integration. The power supply regulation function is directly controlled by the digital circuits on the processor and the software running on the processor. The full digital solution allows you to employ techniques that are not possible with an analog solution including proprietary digital compensation algorithms, non-linear predictive and adaptive control techniques. The full digital solution customizes the response to power input change or load change events.

Microchip’s 16-bit dsPIC DSCs enable Level 4 solutions. Feedback from the power supply is obtained using high-speed/high-bandwidth ADCs. The power supply is controlled using specialized high-speed PWM peripherals. The PWM module can directly drive all popular power supply topologies and the CPU core allows digital compensation algorithms to be executed quickly.

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
Power Supply Design Integration Levels

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 dsPIC33EPXXGS 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

Phase-Shifted Full-Bridge DC-DC Converter
Which MCU or DSC Should You Choose?

Microchip makes many product families that can be used in a variety of intelligent power applications, enabling you to support the level of digital integration and performance your application requires.

**PIC10F Microcontroller Product Family (Level 1)**
The 6-pin PIC10F family allows digital features to be integrated into any power supply design with minimal BOM impact. The integrated Core Independent Peripherals (CIPs) 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. The PIC10F highlights include:

- 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)

**PIC12F and PIC16F Microcontroller Product Families (Levels 2 and 3)**
The PIC12F devices are available in small 8-pin packages, while PIC16F variants 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

**PIC18F Microcontroller Product Family (Levels 2 and 3)**
The PIC18F product family also has an 8-bit CPU and offers extended performance and memory over the PIC16F device family. The PIC18F device family can operate at speeds up to 16 MIPS and has a hardware multiplier for faster calculation of control algorithms. With similar peripheral sets as the PIC16F family—such as PWMs, ADCs, DACs and comparators—the PIC18F family devices are good matches for configuration or topology control (Level 3). An internal 10- or 12-bit ADC with fast sampling rate can be used to monitor feedback parameters and can monitor input/output voltages and currents. Communication peripherals like EUSART, SPI and I2C can be used to implement remote monitoring and controlling features.

- Up to 16 MIPS execution speed with hardware multiplier
- 8-/10-bit PWMs
- Comp, 5-/8-bit DACs, 10- or 12-bit ADC (with up to 200 kspS sample rate on PIC18F)
- Communication interfaces: EUSART, SPI, I2C, CAN, Ethernet and USB

**MCP19XXX Product Family (Level 3)**
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
Intelligent Power Supply Design Solutions

PIC24F Microcontroller Family
The PIC24F product family is Microchip’s entry-level 16-bit microcontroller, providing a migration path from the PIC18F to extended performance, program memory and RAM. The PIC24F family of devices can operate at speeds up to 16 MIPS and has a hardware multiplier for fast control algorithm computations. Devices are available with multiple UART, SPI and I²C serial communication channels for remote monitoring or control. In addition, these devices also include multiple Input Capture and Output Compare/PWM, comparators and a high-speed 10-bit ADC.

Peripheral Pin Select (PPS) is a key feature of the low-pin-count PIC24F family. It allows you to minimize the cost of your design by selecting the lowest pin count device necessary to meet the system requirements. Other features include:

- Up to 16 MIPS execution speed with hardware multiplier
- Four UART, three SPI and three I²C interfaces
- Nine input capture and nine output compare/PWM modules
- 10-bit ADC with up to 500 ksp/s sample rate
- Three internal comparators
- Integrated USB OTG and embedded host

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, using 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.

dsPIC SMPS and Digital Power Conversion and dsPIC Motor Control and Power Conversion Family

- Large family of code- and pin-compatible Flash devices
- Up to 70 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 1 nanosecond 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 4 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 interfaces

Which MCU or DSC Should You Choose?
## Products

### Select 8-bit PIC10F, PIC12F and PIC16F Microcontrollers

<table>
<thead>
<tr>
<th>Product</th>
<th>Level</th>
<th>Pinos</th>
<th>Flash Memory (KB)</th>
<th>RAM (KB)</th>
<th>EE Bytes</th>
<th>Timer 8-/16-bit</th>
<th>PRG/SC Op Amp</th>
<th>ZCD</th>
<th>Comparator</th>
<th>PWM</th>
<th>ADC</th>
<th>DAC</th>
<th>DSM</th>
<th>EUSART SPI/I²C</th>
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<tr>
<td>PIC10F320</td>
<td>1</td>
<td>6</td>
<td>256</td>
<td>✓ 64</td>
<td>HEF* 2/0</td>
<td>1 x Half Bridge</td>
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<td>3 x 10-bit</td>
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</tbody>
</table>

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

### Select 8-bit PIC18F Microcontrollers

<table>
<thead>
<tr>
<th>Product</th>
<th>Level</th>
<th>Pinos</th>
<th>Flash Memory (KB)</th>
<th>RAM (KB)</th>
<th>Timer 8-/16-bit</th>
<th>CCP/ECCP</th>
<th>ADC</th>
<th>Comparator</th>
<th>UART</th>
<th>MSSP</th>
<th>USB</th>
<th>LCD Segments</th>
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<tbody>
<tr>
<td>PIC18FXX22</td>
<td>2,3</td>
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<td>7/3</td>
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<td>–</td>
<td>192</td>
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</table>

Fore more products, view the parametric tables on [www.microchip.com/power](http://www.microchip.com/power).
## Products

### Select Analog Portfolio for Power Applications

<table>
<thead>
<tr>
<th>Product Line</th>
<th>Example Devices</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Modules</td>
<td>MIC45205, MIC45212, MIC3153</td>
<td>Integrated buck converters, system-in-package including an integrated inductor for the simplest, lowest-noise, easiest-to-implement power conversion solutions.</td>
</tr>
<tr>
<td>LDOs</td>
<td>MCP1703A, MIC528X, MIC5265, MIC5504, MIC2930X</td>
<td>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.</td>
</tr>
<tr>
<td>Switching Regulators</td>
<td>MIC2199, MIC2290, MIC28512, MCP16331, MIC24046, MIC2605, MCP16251, MCP1642</td>
<td>Switching regulators with enable functions to allow the intelligent power controller to disable subsystems when needed.</td>
</tr>
<tr>
<td>MOSFET Drivers</td>
<td>MCP14A015X, MCP1403/4/5, MIC5021, MIC4608, MCP14700, MIC4605</td>
<td>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.</td>
</tr>
<tr>
<td>Operational Amplifiers</td>
<td>MCP629X, MCP6H9X, MCP600X, MIC6211</td>
<td>High-speed, high-voltage amplifiers scale and condition analog feedback signals for input to a digital controller.</td>
</tr>
<tr>
<td>Load Switches</td>
<td>MIC2025, MIC94063, MIC2026, MIC2544</td>
<td>Load switches allow management and sequencing of power to subsystems, intelligently responding to environmental factors monitored by the intelligent power supply controller.</td>
</tr>
<tr>
<td>Temperature Sensors</td>
<td>MCP9800/4, MCP9509, MCP9700</td>
<td>Temperature sensors provide high-accuracy, local temperature measurement and over-temperature warnings with a variety of interface outputs for communicating with digital controllers.</td>
</tr>
<tr>
<td>PWM Controllers</td>
<td>MCP19035, MCP1632, MIC2125/6, MIC2103/4</td>
<td>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.</td>
</tr>
<tr>
<td>Digitally-Enhanced Power Analog Controllers</td>
<td>MCP19119, MCP19115</td>
<td>The benefits of a digital power supply are incorporated into a highly integrated single device to create a flexible digital system with minimal component requirements. These devices feature integrated linear regulators, MOSFET drivers, analog PWM controllers and supervisory microcontrollers.</td>
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</table>

### Select dsPIC33 SMPS and Digital Power Conversion Family

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<tr>
<th>Product</th>
<th>Pins</th>
<th>Flash (KB)</th>
<th>RAM (Bytes)</th>
<th>IC/OC</th>
<th>PS PWM</th>
<th>ADC</th>
<th>PGAs*</th>
<th>Analog Compare</th>
<th>UART/ PCI / SPI</th>
<th>CAN</th>
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<td>dsPIC33FJ64GS610</td>
<td>100</td>
<td>64</td>
<td>9 K</td>
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<tr>
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<td>0/1/0</td>
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</table>

*Programmable Gain Amplifiers

For more products, view the parametric tables on [www.microchip.com/power](http://www.microchip.com/power).
Intelligent Power Reference Designs

Reference Designs

Platinum Rated 720 W AC/DC Reference Design
Demonstrating the flexibility of dsPIC DSCs in Switch Mode Power 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.

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.

DC/DC LLC Resonant Converter Reference Design
A single dsPIC33F “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.

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.

Digital Pure Sine Wave Uninterruptible 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.

Grid Connected Solar Micro Inverter 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).

Additional information for all reference designs is available at www.microchip.com/power.
Intelligent Power Development Systems

Microchip offers a number of development boards and advanced development tools which provide an easy and economical way to evaluate intelligent power supply solutions. Included with the development boards are software, documentation and hands-on exercises that allow you to quickly begin designing intelligent power solutions.

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™ 3 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 your 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.

Explorer 16 Development Board (DM240001)

The Explorer 16 is a low-cost, efficient development board to evaluate the features and performance of Microchip’s 16-bit PIC24F and PIC24H MCU, dsPIC33 DSC and 32-bit PIC32MX families. Interface it with the MPLAB® ICD 3 In-Circuit Debugger or MPLAB REAL ICE™ In-Circuit Emulator to speed evaluation and prototyping of application circuitry. This board features an alphanumeric display and Microchip’s TC1047A high-accuracy analog output temperature sensor. The board supports plug-in-modules for 28-, 44- and 100-pin dsPIC DSC devices. A PICtail™ Plus connector on the board allows for easy system expansion.

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.

Digital LED Lighting Development Kit (DM330014)

The LED lighting development kit enables you to quickly leverage the capabilities and performance of the dsPIC33 “GS” DSCs to create a 100% digitally controlled ballast function, while including advanced features such as dimming and color hue control. The dsPIC33 “GS” devices can support an entire system implementation for LED lighting products, including power-conversion circuits, such as AC-to-DC and DC-to-DC conversion, along with function such as Power Factor Corrections (PFC).

Tools and Libraries

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/dsPIC33EP-GS.
Intelligent Power Supply Training and Resources

Making Your Power Applications Intelligent The Easy Way!
- Log on to www.microchip.com/webseminars for FREE web seminars on Intelligent Power Supply designs.
- Register for Design Workshops at www.microchip.com/Biricha.

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<tr>
<th>Web Seminar Title</th>
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<th>Duration</th>
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<td>Quarter Brick Phase Shifted Full Bridge DC/DC Converter</td>
<td>English</td>
<td>20 min</td>
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<tr>
<td>LCC Resonant Converter Reference Design Using the dsPIC DSC</td>
<td>English</td>
<td>20 min</td>
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<tr>
<td>Microchip's Grid Connected Solar Microinverter Reference Design</td>
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<tr>
<td>Controlling High Brightness LEDs using the dsPIC DSC</td>
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<td>Control System Design for Power Converters</td>
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<tr>
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<td>SMPS Buck Converter Design Example</td>
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<td>Introduction to SMPS Control Techniques</td>
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<td>Introduction to the dsPIC DSC SMPS (Part 1)</td>
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<td>Introduction to the dsPIC DSC SMPS (Part 2)</td>
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<td>Building a dsPIC DSC SMPS System</td>
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<td>Offline UPS Reference Design Using the dsPIC DSC</td>
<td>English</td>
<td>30 min</td>
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Want to Learn From an Expert?
Log on to www.microchip.com/RTC and sign up for a formal, hands-on session taught by Microchip experts. You can learn the theories and put them into practice. Additional classes are available covering various topics such as device architecture, peripheral configuration and device programming, C language, development tools, analog products and their usage.

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

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<td>New Components and Design Methods Bring Intelligence to Battery Charger Applications</td>
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### Getting Started

The Microchip website ([www.microchip.com](http://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](http://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](http://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.
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