Intelligent Lighting and Control

Summary
Microchip can meet the technical needs of lighting engineers with its large array of 8-, 16-, 32-bit PIC® microcontrollers, analog, wireless, and human interface products. With advanced peripheral integration and support for all lighting technologies, a scalable Microchip solution provides significant flexibility versus that of a pure analog or ASIC implementation. Designing with Microchip-based intelligent lighting solutions and control enables innovation that expands lighting product capabilities and provides product differentiation.

Light-emitting diode (LED) and fluorescent technologies are currently at the forefront of delivering the most efficient alternatives to incandescent lighting. Although both pose technical challenges, they also offer significant advantages beyond simple incandescent light bulb replacement, including improved efficacy (lumens/watt), reduced energy consumption and the ability to add intelligence.

Because the light quality of these alternate lighting technologies is perceived to be similar to that of incandescent lighting, the benefits of longer life and increased energy savings may not always be considered significant enough to motivate changes in the market. Microchip’s advanced lighting solutions offer you the opportunity to incorporate non-traditional capabilities into your lighting designs. Features such as predictive failure and maintenance, energy monitoring, color and temperature maintenance and remote communications and control are just some of the advanced capabilities that can make intelligent lighting solutions more attractive. These advanced capabilities—along with reduced operating, maintenance and energy costs—can quickly translate to significant savings, particularly for corporate and commercial facilities.

Value Proposition
Microchip-based lighting solutions provide opportunities to further enhance any lighting application through product differentiation and an improved user experience.

Intelligence
- Communication and networking
- Lumen and color control
- Environmental sensing
- Thermal management
- Predictive failure and maintenance
- Daylight harvesting
- Smooth dimming control
- Color mixing
- Closed loop lighting control
- Remote fault detection
- User interface and control

Flexible Power
- Flexible power topology support
- High efficiency power conversion
- Failsafe monitoring
- Energy monitoring and control
- Energy harvesting (e.g. solar)
- Battery management and charging

Scalable Design
- Scalable performance
  - 8-, 16-, 32-bit PIC MCUs
  - Analog products
  - Wireless ICs and modules
  - Human interface products
- Customizable solutions
- Ease of use
  - Easy-to-use development tools
  - Reference designs and collateral
  - Lighting design partner specialists

Learn More
Microchip offers various resources to assist you in your next product design. Learn more about Intelligent Lighting and Control solutions from Microchip by visiting us on the web at: www.microchip.com/lighting or emailing us at: lighting@microchip.com.
Intelligent Lighting and Control Solutions

Lighting Technology Basics

Incandescent Lighting Technology

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Cheap</td>
<td>■ Poor efficiency</td>
</tr>
<tr>
<td>■ Large amounts of visible light</td>
<td>• ~10% input energy = light</td>
</tr>
<tr>
<td>■ No electronics required</td>
<td>• ~90% input energy = radiated heat</td>
</tr>
<tr>
<td></td>
<td>• 10-30 lumens/watt (efficiency)</td>
</tr>
<tr>
<td>Incandescent light sources are good at creating large amounts of visible light and even greater amounts of heat. As a result, a typical light bulb is not very efficient—only about 10% of the input energy is output as light with the remaining 90% being wasted as radiated heat. The typical light bulb has a relatively short lifetime—ranging from several hundred to a couple thousand hours—as the extreme heat of the tungsten causes it to evaporate and eventually fail.</td>
<td></td>
</tr>
</tbody>
</table>

Fluorescent Lighting and HID Technology

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Relatively inexpensive</td>
<td>■ Typically requires “warm up”</td>
</tr>
<tr>
<td>• ~75% less energy than incandescent</td>
<td>Can contain mercury</td>
</tr>
<tr>
<td>• More than 70 lumens/watt (efficiency)</td>
<td>Sensitive to environment and orientation</td>
</tr>
<tr>
<td>■ Increased life: &gt; 8,000 hours</td>
<td>■ Moderate light quality</td>
</tr>
<tr>
<td>Typical fluorescent lighting operates by driving a current through a glass enclosure containing an inert gas and mercury. With the help of phosphors, these elements create visible light when they are excited by electricity. High intensity discharge (HID) lamps or arc lamps are similar in function but create visible light through electrically excited gases (plasma) without the use of phosphors. In both glow-discharge lamps and HID lamps, a ballast is required to initiate and maintain this electrical reaction. The ballast kicks starts the electrical-gas reaction with a large amount of energy and then regulates the current back down to a normalized operating current. High-resolution PWM control is required to accurately control this reaction as well as provide smooth dimming control.</td>
<td></td>
</tr>
</tbody>
</table>

LED Lighting Technology

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Best overall efficiency</td>
<td>■ Requires active or passive thermal solution to remove conducted heat</td>
</tr>
<tr>
<td>• ~25-50% less energy than fluorescent</td>
<td></td>
</tr>
<tr>
<td>• More than 100 lumens/watt (efficiency)</td>
<td></td>
</tr>
<tr>
<td>■ Longest life: &gt; 50,000 hours</td>
<td></td>
</tr>
<tr>
<td>■ No “warm up”, no radiated heat</td>
<td></td>
</tr>
<tr>
<td>■ Good in indoor and outdoor applications</td>
<td></td>
</tr>
<tr>
<td>Similar to a traditional LED, a High Brightness Light Emitting Diode (HBLED) produces light when forward biased, enabling the electron-hole recombination that releases light photons. LED light output is a direct function of the current flow—too little current and the light will dim, too much current and lifetimes will be shortened. A typical LED driver is a DC power supply providing converted AC or DC power to directly control the LED via constant current, Pulse Width Modulation (PWM), or other variations. The LED driver must also provide high efficiencies and power factor correction (PFC) while providing protection from AC line voltage fluctuations. LED drivers can be designed to offer dimming and RGBW color mixing capabilities by either providing a high resolution PWM (or variants such as VFM—Variable Frequency Modulation) signal or varying the constant current.</td>
<td></td>
</tr>
</tbody>
</table>

Constant Current Method

■ Light output maintained by constant current level
■ Dimming control via varying current level
■ Requires high resolution current control

Modulated Current Method

■ Fixed current drive chopped by PWM
■ Dimming control via varying PWM duty cycle
Microchip-based solutions can support any lighting technology as well as add capabilities beyond those of traditional lighting solutions. The flexibility of these solutions allows for simplified attachment to existing designs or the development of full Switch Mode Power Supply (SMPS) based intelligent solutions—and everything in between.

**PIC MCU Attached to Basic Power Supply**

- Simplified design-in
- Customizable features
- Simplified modifications via firmware updates
- Intelligent control capabilities

**SMPS with PIC MCU and Microchip Analog**

- Increased MCU integration
- Fully customizable
- Increased efficiency
- Power Factor Correction (PFC)
- Flexible topologies
- Simplified modifications via firmware updates
- Closed loop control
- High performance PWM and current control
- Intelligent control capabilities

**Energy Harvesting and Battery Charging**

- PIC MCU controlled power conversion and battery storage
- Peak power tracking control, charging and power delivery
- Customizable Maximum Power Point Tracking (MPPT) and battery charging algorithms
- Support for various power supply topologies
- Intelligent control capabilities

The SMPS topologies utilized to regulate the power within lighting applications are the same used within a power supply application. Each SMPS topology has its advantages and determining the proper topology is dependent upon the specific application requirements.

### SMPS Topologies

<table>
<thead>
<tr>
<th>Topology</th>
<th>Vin vs. Vout Relationship</th>
<th>Maximum Power Range</th>
<th>Peak Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buck</td>
<td>VIN &gt; VOUT</td>
<td>1000W</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Boost</td>
<td>VIN &lt; VOUT</td>
<td>150W</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Buck/Boost</td>
<td>VOUT &lt; VIN &lt; VOUT</td>
<td>150W</td>
<td>&gt; 80%</td>
</tr>
<tr>
<td>SEPIC, Cuk. Zeta</td>
<td>VOUT &lt; VIN &lt; VOUT</td>
<td>150W</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Flyback</td>
<td>VOUT &lt; VIN &lt; VOUT</td>
<td>150W</td>
<td>&gt; 80%</td>
</tr>
<tr>
<td>Resonant</td>
<td>VOUT &lt; VIN &lt; VOUT</td>
<td>500W</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Push-Pull</td>
<td>VOUT &lt; VIN &lt; VOUT</td>
<td>1000W</td>
<td>&gt; 90%</td>
</tr>
</tbody>
</table>
Intelligent Lighting and Control Solutions

No matter which lighting technology is used, the ability to effectively control the light source is essential. Replacing a simple on/off switch, advanced lighting control provides the opportunity to incorporate additional intelligence and increase energy savings.

The ability to dim any light source is the most common requirement of a light controller, but it is also a potential design obstacle. Most legacy dimmers are simple TRIAC dimmers that can vary the light output of an incandescent light source from 0–100%. These vary the brightness by “chopping” the AC line voltage and controlling the effective power to the lamp, thereby varying the light output. This method functions well with incandescent sources, as well as with some specially designed CFL ballasts, but does not function properly with most conventional drivers or ballasts. In order to effectively dim LED and fluorescent light, specialized methods such as varying PWM frequency or variable current is required. This is easily implemented with electronic dimming controllers.

Functions such as dimming and timers are becoming commonplace, but intelligent control provides opportunities to enrich the user experience and increase value. Incremental energy savings can be provided by integrating elements such as energy management and harvesting (ie. solar), ambient light compensation (reducing light output based on other localized light sources) and occupancy or motion sensing. Intelligent control enables the creation of lighting networks that communicate locally as well as to remote locations to increase energy savings further and reduce maintenance cost via items such as fixed light output in lighting arrays (ie. street lamps, large rooms, etc.), monitoring light output and providing real-time operating issues. Lighting can also be integrated into other system topologies including security systems or automation and control. Aesthetically, lighting control supports custom mood lighting designs which can vary brightness, color and color temperature across large lighting arrays.

Using Microchip’s intelligent light and control solutions, you can integrate a variety of enhanced capabilities into the luminaire ballast/driver, wall controller or remotes to create additional product differentiation. You are limited only by your creativity in designing differentiated products that offer customizable user interfaces and improved user experience.

### Legacy Control

#### Non-Intelligent Lighting Control
- Mechanical interface
- Limited luminaire control
- No user feedback
- No communication
- No product differentiation

### Intelligent Control

#### mTouch™ Capacitive Touch *(all PIC MCU families)*
- Metal over cap capability
- Projected capacitive capability

#### Segmented LCD *(PIC16, PIC18, PIC24)*
- Up to 480 segments
- Low power display modes
- Contrast control

#### Graphics *(PIC24, PIC32, dsPIC DSC)*
- Integrated graphics controllers
- Direct drive for QVGA and W-QVGA

#### Audio *(PIC18, PIC24, PIC32, dsPIC DSC)*
- Mode for iPod® and Android™ accessories

#### Communication *(all PIC MCU families)*
- Intelligent luminaire control
- DALI, DMX512, LIN/CAN, wireless, others...
- FREE code libraries

#### Gesture Control *(GestIC® Technology)*
- Recognition of 3D hand gestures
Communications and Networking

Microchip solutions provide the versatility to support legacy lighting communications protocols as well as protocols that are just emerging in the lighting industry. Our FREE code libraries and examples for PIC MCUs help you quickly add a wide array of communication options to any lighting application. The versatility of a Microchip-based solution enables the creation of customized communications gateways and networks that allow for interoperability of multiple protocols.

### Wired Protocols
- **DALI**
- **DMX512A**
- **0–10V**
- **PLC**
- **LIN**
- **CAN**
- **RS232/RS485**
- **USB LS/FS**
- **Ethernet**

### Wireless Protocols
- **Wi-Fi 802.11 modules**
- **Bluetooth®**
- **ZigBee®**
- **MiWi™ wireless networking protocol 802.15.4 modules**
- **Stacks for PIC MCUs**
- **Infrared/IrDA®**

### 0–10V
0–10V is the simplest and most prevalent lighting communication protocol. Scaling from 0 to 10V, communication is based on varying the voltage levels. This is useful for dimming, as well as responding to external input sources, such as sensors, remotes, wall-box controls and automation.

### Digital Addressable Lighting Interface (DALI)
DALI is a standard lighting control protocol for large networked lighting systems. DALI provides bi-directional communications with uniquely addressed light sources. This allows for customized lighting schemes and the ability for the light source to relay output level, color and other information back to the controller. Microchip offers FREE DALI code libraries to simplify development—available at www.microchip.com/lightingcomms.

### Digital Multiplex 512 bytes (DMX512)
DMX512A is another successor to 0–10V which provides dimming communication. Used heavily within stage and theatrical lighting applications, DMX512A provides unidirectional lighting communication and control of various stage effects. Microchip offers FREE DMX512A code libraries to simplify development—available at www.microchip.com/lightingcomms.

### CAN and LIN
CAN and LIN protocols were originally created for the automotive market. CAN was designed as a high-reliability and high-speed protocol (up to 1 Mbit/s) for the harsh environment of the car electrical bus. LIN was later added as a simple low-cost alternative for the control of non-critical modules on a vehicle. Due to their inherent robustness, these protocols are becoming more commonly used in non-automotive applications, specifically within industrial and commercial lighting environments. Learn more at www.microchip.com/LIN and www.microchip.com/CAN.

### Ethernet
Ethernet connectivity is becoming ubiquitous. As lower-cost solutions are now more available, it is becoming easier to use Ethernet for even the simplest control and diagnostic applications. Learn more at www.microchip.com/ethernet.

### ZigBee
ZigBee is an industry standard protocol for wireless networking. Specifically designed for low-cost and relatively low-bandwidth automation applications, it allows for quick deployment of flexible network topologies including star, cluster and mesh. Learn more at www.microchip.com/zigbee.

### MiWi Wireless Networking Protocol
The MiWi wireless networking protocol is the most cost-effective wireless protocol designed for low-data-rate, short-distance, low-cost networks. Fundamentally based on IEEE 802.15.4™ for wireless personal area networks (WPANs), the MiWi wireless networking protocol is Microchip’s proprietary RF protocol with FCC-certified modules—providing an easy-to-use and low-cost alternative for wireless communication. Learn more at www.microchip.com/miwi.

### Wi-Fi
Wi-Fi is the most common of all wireless protocols. Microchip’s Wi-Fi modules have been architected to ease integration at minimum system cost. FCC-certified modules are readily available to minimize design effort and time. Learn more at www.microchip.com/wireless.
Intelligent Lighting and Control Solutions

**Scalable Product Solutions**

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>- Luminaire ballast and LED drivers</td>
<td>- Advanced controllers and luminaires</td>
<td>- High-voltage offline LED driver ICs</td>
<td></td>
</tr>
<tr>
<td>- Wall and remote controls</td>
<td>- Advanced communication and networking</td>
<td>- Broad portfolio of DC/DC power conversion solutions</td>
<td></td>
</tr>
<tr>
<td>- Intelligent control capabilities</td>
<td>- Power line carrier (PLC)</td>
<td>- SMBus and I²C™ temperature sensors</td>
<td></td>
</tr>
<tr>
<td>- Communication and networking</td>
<td>- Advanced intelligent control capabilities</td>
<td>- Highly configurable PWM controllers</td>
<td></td>
</tr>
<tr>
<td>- &lt; 100W Optimized power conversion</td>
<td>- &gt; 100W Advanced power conversion</td>
<td>- Complementary PIC MCU compatible regulators, drivers</td>
<td></td>
</tr>
<tr>
<td>- Lowest cost</td>
<td>- Increased performance</td>
<td>and sensors</td>
<td></td>
</tr>
<tr>
<td>- Smallest form factors</td>
<td>- Increased lighting channels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Focus Peripherals Integration**

Microchip is a leading provider of microcontrollers by continually investing and expanding upon its extensive line of PIC microcontrollers. Emphasis is constantly focused on reducing costs while developing products with a strong mix of digital and analog peripherals such as LCD drive, DACs, op amps, PWMs, ADCs, comparators, timers and communication. In addition to the standard peripherals, Microchip continuously brings additional value to PIC microcontrollers by developing unique and exclusive peripherals. These unique peripherals allow you to simplify your embedded lighting designs and develop more creative applications and products. The following PIC microcontroller’s integrated peripherals are available to assist you in designing innovative lighting products. Learn more about Microchip’s “Core Independent Peripherals” at www.microchip.com/CIP.

**Peripheral Summary**

<table>
<thead>
<tr>
<th>Peripheral</th>
<th>Capability</th>
<th>Product Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Resolution PWM (HRPWM)</td>
<td>Smooth dimming, accurate color mixing</td>
<td>All PIC® microcontrollers with NCO and CLC</td>
</tr>
<tr>
<td>Programmable Switch Mode Controller (PSMC)</td>
<td>Efficient, autonomous power conversion</td>
<td>PIC16F178X Family</td>
</tr>
<tr>
<td>Complementary Output Generator (COG)</td>
<td>Automated complementary output for simplified design of high-efficiency LED drive circuits</td>
<td>PIC12F752, PIC16F785</td>
</tr>
<tr>
<td>Complementary Waveform Generator (CWG)</td>
<td>Non-overlapping waveform generator for versatile lighting control</td>
<td>PIC10F32X Family, PIC16F150X Family</td>
</tr>
<tr>
<td>Numerically Controller Oscillator (NCO)</td>
<td>Precision linear frequency generator for building power conversion function</td>
<td>PIC10F32X Family, PIC16F150X Family</td>
</tr>
<tr>
<td>Configurable Logic Cell (CLC)</td>
<td>Configurable combinational and sequential logic for combining functional blocks in lighting driver and control systems</td>
<td>PIC10F32X Family, PIC16F150X Family</td>
</tr>
<tr>
<td>Hardware Limit Timer</td>
<td>Hardware monitoring for fault detection in lighting systems</td>
<td>PIC16F161X Family, PIC12F752, PIC12F753</td>
</tr>
<tr>
<td>Zero Crossing Detect (ZCD)</td>
<td>Precise dimming and switching control</td>
<td>PIC16161X Family, PIC16170X Family, PIC16171X Family</td>
</tr>
<tr>
<td>Slope Compensation</td>
<td>Performs slope compensation function for Peak Current Mode LED drivers</td>
<td>PIC16F753</td>
</tr>
</tbody>
</table>
Scalable Product Solutions

High Resolution PWM (HRPWM)

- > 16-bit effective PWM resolution at high frequency (eg. ~ 16-bit @ 500 kHz)
- Requires Numerically Controlled Oscillator (NCO) and Configurable Logic Cell (CLC)
- Improved EMI performance
- Higher frequency operation
- Results in reduced sizing of inductors and capacitors
- Application Note: AN1476 – Combining the CLC and NCO to Implement a High Resolution PWM

Conventional PWM vs. HRPWM

<table>
<thead>
<tr>
<th></th>
<th>Conventional PWM</th>
<th>HRPWM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PWM Resolution</strong></td>
<td>16-bit</td>
<td>variable</td>
</tr>
<tr>
<td><strong>PWM Clock Frequency</strong></td>
<td>16 MHz</td>
<td>16 MHz</td>
</tr>
<tr>
<td><strong>Target Switching Frequency</strong></td>
<td>500 kHz</td>
<td>500 kHz</td>
</tr>
<tr>
<td><strong>Target Period Width</strong></td>
<td>1 + 500 kHz = 2 µs</td>
<td>1 + 500 kHz = 2 µs</td>
</tr>
<tr>
<td><strong>Best PWM Pulse Adjustment</strong></td>
<td>1 + 16 MHz = 62.5 ns</td>
<td>15.26 ps**</td>
</tr>
<tr>
<td><strong>Maximum # of Steps per Period</strong></td>
<td>2 µs + 62.5 ns = 32</td>
<td>2 µs + 15.26 ps = 131,072</td>
</tr>
<tr>
<td><strong>Effective Full Range PWM Resolution</strong></td>
<td>log₂32 = 5 bits</td>
<td>log₂131,072 = 17 bits</td>
</tr>
</tbody>
</table>

**Reference Application Note AN1476

Programmable Switch Mode Controller (PSMC)

- Single 16-bit PWM with up to six steerable outputs
- Complementary 16-bit PWM with up to three steerable output pairs
- Clock sources: external, system clock, independent 64 MHz oscillator
- Input sources: comparators, external pins
- Blanking control for transient filtering 1
- Independent rising/falling edge control 2
- Dead band with independent rise and fall control 3/4
- Polarity control/auto shutdown and restart
- Flexible PWM output modes
- Burst Mode: externally control activate/deactivate
Scalable Product Solutions

Complementary Waveform Generator (CWG)/Complementary Output Generator (COG)

- Provides non-overlapping complementary waveform
- Various input sources including comparators, PWM, CLC, NCO
- Blanking control for transient filtering (COG only)
- Phase control for output delay (COG only)
- Independent rise and fall
- Dead band control
- Auto shutdown/restart
- Polarity control

Key Features

- Up to 20-bit frequency resolution
- Multiple internal and external clock sources available
- 16-bit numeric frequency control
  - 625 kHz max output with 20 MHz oscillator
  - 0.03 Hz min step size with 31 kHz internal oscillator
- Two Output modes
  - Fixed 50% duty cycle
  - Pulse Frequency Modulation (PFM)

Benefits

- True linear frequency control
- Increased frequency resolution
- Smooth fluorescent ballast dimming control

Numerically Controlled Oscillator (NCO)

Oscillator Capabilities with True Linear Frequency Control

Key Features

- User-configurable real-time logic control
- CLC configuration GUI for quick turn development
- Combinational logic functions
  - AND/OR/XOR/NOT/NAND/NOR/XNOR
- State Functions/Clock
  - D Flip-Flop, JK Flip-Flop D Latch, SR Latch
- Input source from external pins and peripherals
- Output available to external pins and peripherals
- Operation while in Sleep

PIC® Microcontroller

NCO

ADC

Light Output

NCO provides linear control over entire range

Configurable Logic Cell (CLC)
### Focus PIC® Microcontrollers

#### 8-BIT PIC® MICROCONTROLLERS

<table>
<thead>
<tr>
<th>Device</th>
<th>Flash Memory (B)</th>
<th>Pins</th>
<th>ADC</th>
<th>Comparator</th>
<th>Op Amps</th>
<th>DAC (8b, 9b, 10b)</th>
<th>PWM (10b, 16b)</th>
<th>CLC</th>
<th>NCO</th>
<th>CLCNCOCWG/COGPSMCHRPWM</th>
<th>Slope Compensation</th>
<th>ZCD</th>
<th>High-Current Drive (50 mA, 100 mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC10F320</td>
<td>448</td>
<td>6</td>
<td>3 x 8-bit</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2/0</td>
<td>1</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>PIC10F322</td>
<td>896</td>
<td>6</td>
<td>3 x 8-bit</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2/0</td>
<td>1</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>PIC12F1501</td>
<td>1.75K</td>
<td>8</td>
<td>4 x 10-bit</td>
<td>1</td>
<td>–</td>
<td>1/0/0/0</td>
<td>4/0</td>
<td>2</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>PIC16F1503</td>
<td>3.5K</td>
<td>14</td>
<td>8 x 10-bit</td>
<td>2</td>
<td>–</td>
<td>1/0/0/0</td>
<td>4/0</td>
<td>2</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
<td>–</td>
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</tr>
<tr>
<td>PIC16F1507</td>
<td>3.5K</td>
<td>20</td>
<td>12 x 10-bit</td>
<td>–</td>
<td>–</td>
<td>1/0/0/0</td>
<td>4/0</td>
<td>2</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
<td>–</td>
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<tr>
<td>PIC16F1509</td>
<td>7K</td>
<td>20</td>
<td>12 x 10-bit</td>
<td>2</td>
<td>–</td>
<td>1/0/0/0</td>
<td>4/0</td>
<td>4</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>PIC12F1511</td>
<td>1.75K</td>
<td>8</td>
<td>4 x 10-bit</td>
<td>1</td>
<td>–</td>
<td>1/0/0/0</td>
<td>0/3</td>
<td>–</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
<td>–</td>
<td>–</td>
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Focus Microchip Products

### 16-BIT PIC® MICROCONTROLLERS

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**Focus Analog Products**

### DIGITALY-ENHANCED PWM CONTROLLERS WITH INTEGRATED MCU

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<th>Topology Support</th>
<th>Vsupply (V)</th>
<th>Fsw (Max)</th>
<th>Program Memory Size (k words)</th>
<th>RAM (bytes)</th>
<th>Operating Temperature (°C)</th>
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<td>Synchronous buck controller, integrated MCU, LDO and synchronous MOSFET driver, user configurable/programmable</td>
<td>Buck</td>
<td>4.5–32</td>
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<td>MCP19114/5</td>
<td>Low-side drive PWM controller offers multiple power conversion topology support, integrated MCU, LDO and synchronous low-side MOSFET driver, user configurable/programmable</td>
<td>Boost, Flyback, SEPIC, Cuk</td>
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### ANALOG PWM CONTROLLER WITH INTEGRATED MOSFET DRIVER

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<th>Fsw (kHz) (Max)</th>
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<td>Current-mode PWM controller with integrated low-side MOSFET driver</td>
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<td>MCP1631/</td>
<td>Current-mode PWM controller with integrated low-side MOSFET driver, integrated 16V LDC</td>
<td>Boost, SEPIC, Flyback</td>
<td>3.16</td>
<td>3.7</td>
<td>2000</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP1632</td>
<td>Current- or voltage-mode PWM controller with integrated low-side MOSFET driver</td>
<td>Boost, Buck-Boost, SEPIC, Cuk</td>
<td>3.0–5.5</td>
<td>5</td>
<td>600</td>
<td>−40 to +125</td>
</tr>
</tbody>
</table>

### SEQUENTIAL LINEAR LED DRIVER

<table>
<thead>
<tr>
<th>Device</th>
<th>Vin (VAC)</th>
<th>Vout (VDC)</th>
<th>Output Current (peak)</th>
<th>Dimming</th>
<th>Parallelable</th>
<th>Packages</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL8800</td>
<td>90–275</td>
<td>70–350</td>
<td>115 mA</td>
<td>External dimmer</td>
<td>✓</td>
<td>33-pin QFN</td>
<td>6-Stage</td>
</tr>
<tr>
<td>CL8801</td>
<td>90–275</td>
<td>70–350</td>
<td>200 mA</td>
<td>External dimmer</td>
<td>✓</td>
<td>33-pin QFN</td>
<td>4-Stage</td>
</tr>
</tbody>
</table>

### VOLTAGE REGULATORS

<table>
<thead>
<tr>
<th>Device</th>
<th>Topology Support</th>
<th>Vsupply (V)</th>
<th>Output Voltage (V)</th>
<th>Output Current (mA)</th>
<th>Iq (Typical) (μA)</th>
<th>Fsw (kHz) (Max)</th>
<th>Operating Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP1623/4</td>
<td>Boost</td>
<td>0.35–5.5</td>
<td>2.0–5.5</td>
<td>175</td>
<td>19</td>
<td>500</td>
<td>−40 to +85</td>
</tr>
<tr>
<td>MCP1625/1</td>
<td>Boost</td>
<td>0.82–5.5</td>
<td>1.8–5.5</td>
<td>225</td>
<td>14</td>
<td>500</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP1640</td>
<td>Boost</td>
<td>0.65–5.5</td>
<td>2.0–5.5</td>
<td>350</td>
<td>19</td>
<td>500</td>
<td>−40 to +85</td>
</tr>
<tr>
<td>MCP1643</td>
<td>Boost</td>
<td>0.5–5.0 (HV: 36V)</td>
<td>0.6–5.0</td>
<td>550</td>
<td>30</td>
<td>1000</td>
<td>−40 to +85</td>
</tr>
<tr>
<td>MCP16301/HV</td>
<td>Buck</td>
<td>4.0–30</td>
<td>2.0–15</td>
<td>600</td>
<td>2000</td>
<td>500</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP16311/2</td>
<td>Buck</td>
<td>4.4–30</td>
<td>2.0–24</td>
<td>1000</td>
<td>85</td>
<td>500</td>
<td>−40 to +125</td>
</tr>
</tbody>
</table>
## Focus Microchip Products

### Focus Analog Products

#### POWER MOSFET DRIVER

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
<th>Number of Channels</th>
<th>Vsupply (V)</th>
<th>Peak Drive Strength (A)</th>
<th>Output Resistance (Ri/Ro, Ω-max)</th>
<th>Input/Output Delay (ns)</th>
<th>Operating Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP1401/42</td>
<td>Low-side MOSFET Drivers, 0.5A Peak Output Current</td>
<td>Single</td>
<td>18</td>
<td>0.5</td>
<td>12/10</td>
<td>35/35</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP1415/42</td>
<td>Low-side MOSFET Drivers, 1.5A Peak Output Current</td>
<td>Single</td>
<td>18</td>
<td>1.5</td>
<td>6/4</td>
<td>41/48</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP1467/8B</td>
<td>Low-side MOSFET Drivers, 2.0A Peak Output Current</td>
<td>Dual</td>
<td>18</td>
<td>2.0</td>
<td>5/5</td>
<td>45/45</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP1469/10/11</td>
<td>Low-side MOSFET Drivers, 3.0A Peak Output Current</td>
<td>Dual</td>
<td>18</td>
<td>3.0</td>
<td>4/4</td>
<td>45/45</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP14E3/4/5</td>
<td>Low-Side MOSFET Drivers, 4.0A Peak Output Current</td>
<td>Dual</td>
<td>18</td>
<td>4.0</td>
<td>2.5/2.5</td>
<td>56/50</td>
<td>−40 to +125</td>
</tr>
<tr>
<td>MCP14628</td>
<td>Synchronous (High-Side/Low-Side) MOSFET Driver</td>
<td>(high/low)</td>
<td>5</td>
<td>2.0, 3.5 (low side sink only)</td>
<td>1.0/1.0 (high side) 1.0/0.5 (low side)</td>
<td>15/18 (high side) 16/22 (low side)</td>
<td>−40 to +85</td>
</tr>
<tr>
<td>MCP14700</td>
<td>Synchronous (High-Side/Low-Side) MOSFET Driver</td>
<td>(high/low)</td>
<td>5</td>
<td>2.0, 3.5 (low side sink only)</td>
<td>1.0/1.0 (high side) 1.0/0.5 (low side)</td>
<td>27/27 (high side) 17/17 (low side)</td>
<td>−40 to +125</td>
</tr>
</tbody>
</table>

#### HIGH-VOLTAGE, LOW-SIDE BUCK LED DRIVER ICS

<table>
<thead>
<tr>
<th>Device</th>
<th>Internal Reference</th>
<th>External Reference</th>
<th>Control Algorithm</th>
<th>Mode</th>
<th>Input Voltage</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV9910B</td>
<td>250 mV ± 10</td>
<td>Vio ± 12 mV</td>
<td>Peak-current mode controller</td>
<td>Fixed freq./Fixed Torr</td>
<td>6–450V</td>
<td>8-pin SO, 16-pin SO</td>
</tr>
<tr>
<td>HV9910C</td>
<td>250 mV ± 10</td>
<td>Vio ± 12 mV</td>
<td>Peak-current mode controller</td>
<td>Fixed freq./Fixed Torr</td>
<td>15–450V</td>
<td>8-pin SO, 16-pin SO</td>
</tr>
<tr>
<td>HV9961</td>
<td>275 mV ± 3</td>
<td>0.182–0.188 Vio ± 10 mV</td>
<td>Average-current mode controller</td>
<td>Fixed Torr</td>
<td>9–450V</td>
<td>8-pin SO, 16-pin SO</td>
</tr>
<tr>
<td>HV9861A</td>
<td>270 mV ± 3</td>
<td>0.176–0.182 Vio ± 10 mV</td>
<td>Average-current mode controller</td>
<td>Fixed Torr</td>
<td>15–450V</td>
<td>8-pin SO, 16-pin SO</td>
</tr>
<tr>
<td>HV9803</td>
<td>–</td>
<td>0.49 Vio ± 16 mV</td>
<td>Average-current mode controller</td>
<td>Fixed Torr</td>
<td>8–16V</td>
<td>8-pin SO</td>
</tr>
<tr>
<td>HV9803B</td>
<td>–</td>
<td>0.495 Vio ± 16 mV</td>
<td>Average-current mode controller</td>
<td>Fixed Torr</td>
<td>8–16V</td>
<td>8-pin SO</td>
</tr>
</tbody>
</table>

#### BOOST/SEPIC LED DRIVERS

<table>
<thead>
<tr>
<th>Device</th>
<th>Number of Channels</th>
<th>Input Voltage</th>
<th>Main Features</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV9911</td>
<td>1</td>
<td>9–250V</td>
<td>Latched mode output short circuit and open circuit protection</td>
<td>16-pin SO</td>
</tr>
<tr>
<td>HV9912</td>
<td>1</td>
<td>9–90V</td>
<td>Hiccup mode output short circuit and open circuit protection</td>
<td>16-pin SO</td>
</tr>
<tr>
<td>HV9964</td>
<td>1</td>
<td>8–40V</td>
<td>High PWM dimming ratio (&gt; 10,000:1), Latched mode open-loop protection</td>
<td>16-pin SO</td>
</tr>
<tr>
<td>HV9982</td>
<td>3</td>
<td>10–40V</td>
<td>Three channel LED driver, Hiccup mode output short circuit and open circuit protection</td>
<td>40-pin QFN</td>
</tr>
<tr>
<td>HV9985</td>
<td>3</td>
<td>10–40V</td>
<td>Three channel LED driver optimized for driving logic level FETs</td>
<td>40-pin QFN</td>
</tr>
<tr>
<td>HV9986</td>
<td>3</td>
<td>10–40V</td>
<td>Independent open circuit and short circuit protection for each channel</td>
<td>40-pin QFN</td>
</tr>
</tbody>
</table>

#### DC/DC LED DRIVER ICS

<table>
<thead>
<tr>
<th>Device</th>
<th>Input Voltage</th>
<th>Topology Support</th>
<th>Control Algorithm</th>
<th>Main Features</th>
<th>Automotive Qualified</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV9918</td>
<td>4.5–40V</td>
<td>Buck</td>
<td>Hysteric</td>
<td>Integrated 40V, 1Ω switching FET, On-board Analog-to-PWM conversion</td>
<td>–</td>
<td>8-pin DFN</td>
</tr>
<tr>
<td>HV9919B</td>
<td>4.5–40V</td>
<td>Buck</td>
<td>Hysteric</td>
<td>0.5A source and 1A sink gate driver for logic level FETs, On-board Analog-to-PWM conversion</td>
<td>–</td>
<td>8-pin DFN</td>
</tr>
<tr>
<td>HV9930</td>
<td>8–200V</td>
<td>Boost-Buck (Qik)</td>
<td>Hysteric</td>
<td>Programmable input current limit, Excellent input voltage transient rejection</td>
<td>–</td>
<td>8-pin SO</td>
</tr>
<tr>
<td>HV9967B</td>
<td>8–60V</td>
<td>Buck</td>
<td>Average mode</td>
<td>Integrated 60V, 0.8Ω switching FET, Output short circuit and over temperature protection</td>
<td>–</td>
<td>8-pin MSOR 8-pin DFN</td>
</tr>
<tr>
<td>AT9917</td>
<td>5.3–40V</td>
<td>Boost/SEPIC</td>
<td>Closed loop/Fixed Freq.</td>
<td>Programmable thermal fold back profile, low shutdown quiescent current</td>
<td>✓</td>
<td>24-pin TSSOP</td>
</tr>
<tr>
<td>AT9919B</td>
<td>4.5–40V</td>
<td>Buck</td>
<td>Hysteric</td>
<td>0.5A source and 1A sink gate driver for logic level FETs, On-board Analog-to-PWM conversion</td>
<td>✓</td>
<td>8-pin DFN</td>
</tr>
<tr>
<td>AT9932</td>
<td>5.3–40V</td>
<td>Boost-Buck (Qik)</td>
<td>Closed loop/Fixed Freq.</td>
<td>Excellent input voltage transient rejection, Programmable thermal fold back profile</td>
<td>✓</td>
<td>24-pin TSSOP</td>
</tr>
<tr>
<td>AT9933</td>
<td>8–75V</td>
<td>Boost-Buck (Qik)</td>
<td>Hysteric</td>
<td>Programmable input current limit, Excellent input voltage transient rejection</td>
<td>✓</td>
<td>8-pin SO</td>
</tr>
</tbody>
</table>

#### THERMAL MANAGEMENT: Temperature Sensors

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
<th># Temps Monitored</th>
<th>Typical/Max Accuracy (°C)</th>
<th>Operating Temperature (°C)</th>
<th>Vcc Range (V)</th>
<th>Typical Supply Current (µA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP9800/1</td>
<td>SMBus/I²C™ temperature sensor</td>
<td>1</td>
<td>0.5/1.0</td>
<td>−40 to +125</td>
<td>2.8–5.5</td>
<td>200</td>
</tr>
<tr>
<td>TCN7A</td>
<td>SMBus/I²C temperature sensor</td>
<td>1</td>
<td>0.5/3.0</td>
<td>−40 to +125</td>
<td>2.8–5.5</td>
<td>200</td>
</tr>
<tr>
<td>MCP9700/01</td>
<td>Voltage output temperature sensor</td>
<td>1</td>
<td>1.0/4.0</td>
<td>−40 to +125</td>
<td>2.3–5.5</td>
<td>200</td>
</tr>
<tr>
<td>EMC1412/3/4</td>
<td>SMBus/I²C multi temperature sensor</td>
<td>2/3/4</td>
<td>0.25/1.0</td>
<td>−40 to +125</td>
<td>3.0–3.6</td>
<td>430</td>
</tr>
<tr>
<td>MCP9808</td>
<td>SMBus/I²C temperature sensor</td>
<td>1</td>
<td>0.25/5.0</td>
<td>−40 to +125</td>
<td>2.7–5.5</td>
<td>200</td>
</tr>
<tr>
<td>MCP9501/2/3/4</td>
<td>Factory programmed temperature switch</td>
<td>1</td>
<td>1/6</td>
<td>−40 to +125</td>
<td>2.7–6.5</td>
<td>25</td>
</tr>
<tr>
<td>MCP9509/10</td>
<td>Resistor programmable temperature switch</td>
<td>1</td>
<td>0.5/2</td>
<td>−40 to +125</td>
<td>2.7–6.5</td>
<td>30</td>
</tr>
</tbody>
</table>
**Focus Microchip Products**

### WIRELESS PRODUCTS

<table>
<thead>
<tr>
<th>Product</th>
<th>Pins</th>
<th>Frequency Range (GHz)</th>
<th>Sensitivity (dBm)</th>
<th>Power Output (dBm)</th>
<th>MAC Profiles</th>
<th>Encryption</th>
</tr>
</thead>
<tbody>
<tr>
<td>RN171</td>
<td>49</td>
<td>2.412–2.484</td>
<td>−83</td>
<td>0 to +12</td>
<td>DHCP, DNS, ARP, ICMP, FTP client, HTTP client, TCP, UDP</td>
<td>WEP, WPA, WPA2, EAP</td>
</tr>
<tr>
<td>MRF24WG0MA</td>
<td>36</td>
<td>2.412–2.484</td>
<td>−95</td>
<td>18</td>
<td>Wi-Fi® Connection Manager, Announce, DNS, DDNS, DHCP, FTP, HTTP, NBNS, SNMP, SNTP, SSL, TCP, UDP, ZeroConf(1)</td>
<td>WPA2-PSK, WPA-PSK, WEP, WPA2-ENTERPRISE</td>
</tr>
<tr>
<td>MRF24WG0MB</td>
<td>36</td>
<td>2.412–2.484</td>
<td>−95</td>
<td>18</td>
<td>Wi-Fi Connection Manager, Announce, DNS, DDNS, DHCP, FTP, HTTP, NBNS, SNMP, SNTP, SSL, TCP, UDP, ZeroConf(1)</td>
<td>WPA2-PSK, WPA-PSK, WEP, WPA2-ENTERPRISE</td>
</tr>
<tr>
<td>RN131</td>
<td>44</td>
<td>2.412–2.484</td>
<td>−85</td>
<td>18</td>
<td>DHCP, DNS, ARP, ICMP, FTP client, HTTP client, TCP, UDP</td>
<td>WEP, WPA, WPA2, EAP</td>
</tr>
</tbody>
</table>

1. Supported in the provided stack.

### IEEE 802.11 Modules

<table>
<thead>
<tr>
<th>Product</th>
<th>Pins</th>
<th>Frequency Range (GHz)</th>
<th>Sensitivity (dBm)</th>
<th>Power Output (dBm)</th>
<th>MAC Profiles</th>
<th>Encryption</th>
</tr>
</thead>
<tbody>
<tr>
<td>RN171</td>
<td>49</td>
<td>2.412–2.484</td>
<td>−83</td>
<td>0 to +12</td>
<td>DHCP, DNS, ARP, ICMP, FTP client, HTTP client, TCP, UDP</td>
<td>WEP, WPA, WPA2, EAP</td>
</tr>
<tr>
<td>MRF24WG0MA</td>
<td>36</td>
<td>2.412–2.484</td>
<td>−95</td>
<td>18</td>
<td>Wi-Fi® Connection Manager, Announce, DNS, DDNS, DHCP, FTP, HTTP, NBNS, SNMP, SNTP, SSL, TCP, UDP, ZeroConf(1)</td>
<td>WPA2-PSK, WPA-PSK, WEP, WPA2-ENTERPRISE</td>
</tr>
<tr>
<td>MRF24WG0MB</td>
<td>36</td>
<td>2.412–2.484</td>
<td>−95</td>
<td>18</td>
<td>Wi-Fi Connection Manager, Announce, DNS, DDNS, DHCP, FTP, HTTP, NBNS, SNMP, SNTP, SSL, TCP, UDP, ZeroConf(1)</td>
<td>WPA2-PSK, WPA-PSK, WEP, WPA2-ENTERPRISE</td>
</tr>
<tr>
<td>RN131</td>
<td>44</td>
<td>2.412–2.484</td>
<td>−85</td>
<td>18</td>
<td>DHCP, DNS, ARP, ICMP, FTP client, HTTP client, TCP, UDP</td>
<td>WEP, WPA, WPA2, EAP</td>
</tr>
</tbody>
</table>

### IEEE 802.15.4 Transceivers/Modules

<table>
<thead>
<tr>
<th>Product</th>
<th>Pins</th>
<th>Frequency Range (MHz)</th>
<th>Sensitivity (dBm)</th>
<th>Power Output (dBm)</th>
<th>MAC Profiles</th>
<th>Encryption</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRF24J40</td>
<td>40</td>
<td>2.405–2.48</td>
<td>−95</td>
<td>0</td>
<td>ZigBee®, MiWi™ wireless networking protocol</td>
<td>AES128</td>
</tr>
<tr>
<td>MRF24J40MA</td>
<td>12</td>
<td>2.405–2.48</td>
<td>−95</td>
<td>0</td>
<td>ZigBee, MiWi wireless networking protocol</td>
<td>AES128</td>
</tr>
<tr>
<td>MRF24J40MD</td>
<td>12</td>
<td>2.405–2.48</td>
<td>−104</td>
<td>20</td>
<td>ZigBee, MiWi wireless networking protocol</td>
<td>AES128</td>
</tr>
<tr>
<td>MRF24J40MC</td>
<td>12</td>
<td>2.405–2.48</td>
<td>−108</td>
<td>20</td>
<td>ZigBee, MiWi wireless networking protocol</td>
<td>AES128</td>
</tr>
</tbody>
</table>

### Bluetooth® Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Pins</th>
<th>Frequency Range (GHz)</th>
<th>Sensitivity (dBm)</th>
<th>Power Output (dBm)</th>
<th>MAC Profiles</th>
<th>Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>RN42</td>
<td>35</td>
<td>2.4 to 2.48</td>
<td>−80</td>
<td>4</td>
<td>Yes</td>
<td>SPP, DUN, HID, iAP, HCI, RFCOMM, L2CAP, SDP</td>
</tr>
<tr>
<td>RN41</td>
<td>35</td>
<td>2.4 to 2.48</td>
<td>−80</td>
<td>15</td>
<td>Yes</td>
<td>SPP, DUN, HID, iAP, HCI, RFCOMM, L2CAP, SDP</td>
</tr>
</tbody>
</table>

### Sub-GHz Transceivers/Modules

<table>
<thead>
<tr>
<th>Product</th>
<th>Pins</th>
<th>Frequency Range (MHz)</th>
<th>Sensitivity (dBm)</th>
<th>Power Output (dBm)</th>
<th>RSSI</th>
<th>Clock</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRF49XA</td>
<td>16</td>
<td>433/868/915</td>
<td>−110</td>
<td>7</td>
<td>Yes</td>
<td>10 MHz</td>
<td>4-wire SPI</td>
</tr>
<tr>
<td>MRF89XA</td>
<td>32</td>
<td>868/915/950</td>
<td>−113</td>
<td>12.5</td>
<td>Yes</td>
<td>12.8 MHz</td>
<td>4-wire SPI</td>
</tr>
<tr>
<td>MRF89XAM8A</td>
<td>12</td>
<td>868</td>
<td>−113</td>
<td>12.5</td>
<td>Yes</td>
<td>12.8 MHz</td>
<td>4-wire SPI</td>
</tr>
<tr>
<td>MRF89XAM9A</td>
<td>12</td>
<td>915</td>
<td>−113</td>
<td>12.5</td>
<td>Yes</td>
<td>12.8 MHz</td>
<td>4-wire SPI</td>
</tr>
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</table>

### ETHERNET PRODUCTS

<table>
<thead>
<tr>
<th>Device Family</th>
<th>Pins</th>
<th>MCU + Ethernet</th>
<th>Integrated MAC + PHY</th>
<th>Interface</th>
<th>Hardware Security</th>
<th>Pre-programmed MAC</th>
<th>Additional Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC18F9790</td>
<td>64–100</td>
<td>✓</td>
<td>✓ (10Base-T)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>IEEE 802.3™ compliant, Auto-negotiation, Configurable buffer</td>
</tr>
<tr>
<td>PIC32MX795F512</td>
<td>64–100</td>
<td>✓</td>
<td>✓ (10/100Base-T)</td>
<td>–</td>
<td>–</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>ENC28J60</td>
<td>28–44</td>
<td>–</td>
<td>✓ (10Base-T)</td>
<td>SPI</td>
<td>–</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>ENC624J600</td>
<td>44–64</td>
<td>–</td>
<td>✓ (10/100Base-T)</td>
<td>SPI/Parallel</td>
<td>✓</td>
<td>✓</td>
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### USB PRODUCTS

<table>
<thead>
<tr>
<th>Device Family</th>
<th>Pins</th>
<th>Flash (KB)</th>
<th>Voltage (V)</th>
<th>Crystal-Free</th>
<th>Additional Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC16F1459</td>
<td>14–20</td>
<td>7–14</td>
<td>1.8–5.5</td>
<td>✓</td>
<td>CWG, 10-bit ADC, DAC, I²C™, SPI, UART</td>
</tr>
<tr>
<td>PIC18F45K50</td>
<td>28–44</td>
<td>16–32</td>
<td>1.8–5.5</td>
<td>✓</td>
<td>10-bit ADC, Comparators, ECCP, UART, I²C</td>
</tr>
<tr>
<td>PIC18F9794</td>
<td>64–100</td>
<td>32–128</td>
<td>2–3.6</td>
<td>✓</td>
<td>VBAT, 12-bit ADC, LCD, ECCP, UART, I²C, SPI, Comparators</td>
</tr>
<tr>
<td>PIC32MX220F032</td>
<td>28–44</td>
<td>16–32</td>
<td>2.3–3.6</td>
<td>–</td>
<td>PWM, 10-bit ADC, SPI, UART, I²C, I²S™</td>
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### CAN AND LIN PRODUCTS

<table>
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<tr>
<th>Device Family</th>
<th>Pins</th>
<th>Flash (KB)</th>
<th>CAN Tx Buffers</th>
<th>CAN Rx Buffers</th>
<th>LIN Tx Rx</th>
<th>Voltage (V)</th>
<th>Additional Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC18F4685</td>
<td>28–44</td>
<td>16–96</td>
<td>3</td>
<td>2</td>
<td>–</td>
<td>2–5.5</td>
<td>LIN USART</td>
</tr>
<tr>
<td>PIC18F66K80</td>
<td>28–64</td>
<td>32–64</td>
<td>3</td>
<td>2</td>
<td>–</td>
<td>1.8–5.5</td>
<td>LIN USART</td>
</tr>
<tr>
<td>PIC16F1829LIN</td>
<td>14</td>
<td>8K</td>
<td>–</td>
<td>–</td>
<td>Integrated</td>
<td>2.3–5.5</td>
<td>LIN USART</td>
</tr>
<tr>
<td>PIC32MX564F128</td>
<td>64–100</td>
<td>16–128</td>
<td>32</td>
<td>32</td>
<td>–</td>
<td>2.3–3.6</td>
<td>LIN USART</td>
</tr>
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Reference Designs and Proofs-of-Concepts

Go to www.microchip.com/lighting and select ‘Tools → Development & Reference Designs’ to download the latest design schematics, firmware, application notes and collateral. Contact your local sales representative to evaluate working demonstration platforms.

PIC16F1947 mTouch Technology Intelligent Lighting Controller

**Highlights**

- PIC16F1947-based design with AC/DC power conversion
- Panel technology and backlighting provided by Lumvatech
- Wall controller
  - Backlit buttons wake up with mTouch technology
- mTouch technology capacitive sensing through light buttons
  - Visually interactive buttons and slider
  - Varying light intensity to indicate pressure
- Variable luminaire control
  - DALI
  - MiWi wireless networking protocol
  - Phase-cut (TRIAC)
- Customizable
  - Buttons, graphics, operating modes
  - Communication (DALI, DMX512A, RF, etc.)
Reference Designs and Proofs-of-Concepts

PIC12F1572 RGB Color Mixing Demonstration

Highlights
- High-resolution color mix with Cree RGB LED
  - PIC12F1572 Controlled Topology
    - Three standalone 16-bit PWMs with independent time base
    - 4 channel 10-bit ADC with voltage reference
    - 5-bit DAC
    - Comparator
    - Complementary Waveform Generator (CWG)
    - EUSART
- PIC16F1455 integrated USB and Active Clock Tuning MCP1640 boost DC/DC regulator

Two Modes of Operation
- Mode 1: PIC12F1572 with MCP1640
  - mTouch technology color control slider
  - Auto rotation of custom color mix
  - Battery system power
- Mode 2: PIC12F1572 with PIC16F1455
  - USB connectivity for chromaticity selector GUI
  - USB system power

Block Diagram
Reference Designs and Proofs-of-Concepts

PIC12F752 High Power LED Flashlight

**Highlights**
- DC/DC Buck Power Conversion
  - > 90% efficient buck power supply
- PIC12F752-based design
- Over temperature monitoring
- Upwards of 1000 lumen output at 10W
- Anodized aluminum enclosure
- Magnetic rotational mode selector
- Multiple operating modes
  - Low power (60 lumens @ 0.6W)
  - Medium power (200 lumens @ 2W)
  - High power (1000 lumens @ 10W)
  - SOS (customized lighting sequence)
- Long life operation
  - Low power = 31 hours @ 0.6W
  - Medium power = 8.5 hours @ 2W
  - High power = 1.5 hours @ 10W

**Block Diagram**

**LED drive and closed loop control determined by current sense and temperature**
- **PIC12F752 Microcontroller**
- **MCP14628 MOSFET Driver**
- **ADC Input**
  - Controls operational modes based on position of selector ring
  - Real-time temperature monitoring of LED for fail-safe operation
- **Resistive Temperature Sensor**
  - LED current sense and feedback to sustain constant light output
  - Synchronous Buck Regulator controlled by PIC12F752 microcontroller for maximum efficiency
- **1000 Lumen output at 10W**

**5b Digital Analog Converter (DAC)**
- Allows the use of smaller current sense resistor
  - High resolution eliminates external op amp
  - Less power consumption and better efficiency
- **Complementary Output Generator (COG)**
  - 1 of 2 available outputs utilized
  - Frequency determined by PWM
  - Provides dead-band control for the synchronous switches
  - Provides blanking control to prevent transient behavior
- **High-Performance Comparators**
  - 40 ns response time

**Mechanics, Optics, and Thermal Solution**
- Provided by AirSpeed

**Ultimate Lithium Batteries**
- Provided by Energizer®

**CREE® LED**
- XM-L LED

**References**
- PIC12F752, MCP1703, MCP14628, and Reference Design
- Provided by Microchip
Reference Designs and Proofs-of-Concepts

PIC12F752 AC/DC LED Driver

Highlights
- AC/DC flyback power supply
  - ~85% Efficiency
  - Active 0.95 Power Factor Correction (PFC)
  - 90–240 Vac input
    - Single hardware platform
    - Firmware based configuration
  - 20 Vdc/375 mA output
- PIC12F752-controlled topology
  - Core independent peripheral integration
    - 5-bit DAC
    - Complementary Output Generator (COG)
    - High performance comparators
    - Hardware Limit Timer (HLT)
- MCP1416 FET Driver
- TRIAC dimmable

Block Diagram

90–240 VAC Input

- PIC12F752 Microcontroller
- HLT @ 50 kHz
- 5-bit DAC
- Firmware
- 10-bit ADC
- Complimentary Output Generator (COG)
- Primary Stage
- Secondary Stage
- MCP1416 MOSFET Driver
- ~20 Vdc/375 mA Output
- Bootstrap Voltage Regulator

MCP1416

LED Terminal

Microchip

Dimmable LED Driver
Reference Designs and Proofs-of-Concepts

**PIC16F1788 Wireless DC/DC LED Driver**

**Highlights**
- DC/DC SEPIC power supply
  - ~90% Efficiency
  - 9–24 Vdc input
  - 24 Vdc output
- **PIC16F1788**-controlled topology
  - Core independent peripheral integration
    - Programmable Switch Mode Controller (PSMC)
    - High-performance 16-bit PWM
    - 10/12-bit ADC
    - High-performance comparators
    - 8-bit DAC
    - Op amps
- Current mode control
- Software PI control
- Variable frequency: 400–700 kHz
- **MCP1416** FET driver
- **MCP16301** voltage regulator
- Wireless communications
  - **MRF24J40MA** MiWi wireless networking protocol module
- Dimming support
  - 0–10V control
  - MiWi wireless networking protocol radio control

**Block Diagram**

- **MCP16301** Regulator
- **MRF24J40MA** MiWi™ Wireless Networking Protocol Module
- 0–10V Input
- 9–24 Vdc Input
- 3.3 Vdc
- **PIC16F1788** Microcontroller
  - SPI Interface
  - Programmable Switch Mode Controller (PSMC)
  - Op Amp
  - Comp.
  - 8-bit DAC
  - Firmware PID Control
- **MCP1416** MOSFET Driver
  - Peak current mode control
  - Voltage divider to prevent over-voltage of load
  - Average current sense and feedback to sustain constant current
- SEPIC LED Drive
- Regulated Output
- = 500 mA

Example Wi-Fi to MiWi Wireless Networking Protocol Topology
PIC16F1509 Solar Powered LED Security Lamp

Highlights

- DC/DC SEPIC power supply
  - ~ 85% Efficiency @ 500 mA charging current
  - 9–25 Vdc input
    (compatible with 30–36 cell panels)
  - 6.8–7.2 Vdc @ 500 mA DC output
    for battery charging
  - 9–24 Vdc @ 350 mA DC output
    for LED driving
- PIC16F1509-controlled topology
- Core independent peripheral integration
  - Numerically Controlled Oscillator (NCO)
  - 10-bit Analog-to-Digital Converter (ADC)
- Maximum power point tracking (MPPT) solar charging to battery
- Night sensing via solar panel
- MCP6V02 op amp for current shunt amplification and motion sensing via Passive Infrared (PIR) sensor
- MCP1790 High Voltage Regulator
- Boost LED drive

Block Diagram
**Reference Designs and Proofs-of-Concepts**

**PIC16F1508 DALI Dimmable Fluorescent Ballast**

**Highlights**
- AC/DC resonant power supply
  - Active Power Factor Correction (PFC)
  - ~90% Efficiency
  - 50 kHz Switching frequency
  - 120–240 Vac input
    - Single hardware platform
    - Firmware based configuration
- **PIC16F1508**-controlled topology
  - Core independent peripheral integration
    - 5-bit DAC, CLC, PWM, NCO and comparators
- DALI communications
- Smooth dimming control
  - Linear frequency control using NCO
- **MCP1416** FET Driver

**Block Diagram**

![Block Diagram of PIC16F1508 DALI Dimmable Fluorescent Ballast](image_url)
Digital HID Ballast Reference Design

**Highlights**
- dsPIC33FJ06GS202-based design
- Xenon HID lamp
- Full digital control HID ballast
  - Ignores HID bulb then transitions to steady-state operation
  - Less than 150 seconds to steady-state light output
- Flyback DC/DC boost converter
  - 9–16 Vdc input
  - Greater than 85% efficiency
- Planar magnetic used to achieve small size
  - 9 mm x 60 mm x 80 mm
  - Commonly referred to as a “slim” ballast form factor
- Under voltage, over voltage, and over current protection

**Block Diagram**

High Resolution PWM Proof of Concept

**Highlights**
- High Resolution PWM (HRPWM)
- >16-bit effective PWM resolution at high frequency (eg. ~16-bit @ 500 kHz)
  - Required peripherals: Numerically Controlled Oscillator (NCO) and Configurable Logic Cell (CLC)
  - Improved EMI performance
- RGBW color mixing control with four PIC microcontrollers with NCO/CLC
  - Single PIC16F1509 for RED and high-resolution color processing
  - Single PIC10F322 per GREEN, BLUE, WHITE channel
  - Variable LED frequency based on brightness: 500 Hz to 64 kHz
    - 16 to 21-bits effective PWM resolution
- USB and DMX512A capable via PIC16F1455

Note: See Application Note AN1476
Intelligent Lighting and Control Solutions

Go to www.microchip.com/lighting and select ‘Tools → Development & Reference Designs’ to purchase as well as download the latest design schematics, firmware, application notes, and collateral.

Lighting Communications Development Platform

- Universal lighting protocol development
- FREE ’C’ library stack (DALI, DMX512A)
- Dimming and color mixing control
- Customizable capabilities

Main Communication Board Highlights (DM160214)

- Populated with PIC16F1947 controlling:
  - Communications
  - User interface: LCD, buttons, slider
  - LED constant current drive
- Populated with Cree XLamp MC-E Color LED
- Populated with the LEDnLIGHT optic and holder

Prototyping Communication Board Highlights (AC160214)

- Populated with PIC16F1947 for user interface and communications
- Breadboarding space for customized lighting development

Universal Communications Adapter Interface

- DALI adapter (DM160214-1)
- DMX512A adapter (DM160214-2)

Available for purchase separately or as a kit

DALI Starter Kit (DV160214-1)
DMX512A Starter Kit (DV160214-2)

- Two DALI or (two) DMX512A adapters
- Two Main communication boards
- Prototyping communication board
- 9V international power supply
- RJ45 patch cable

For more information, visit www.microchip.com/lightingcomms.

MCP16301 LED Driver Demonstration Board (MCP16301 – ARD00410)

- MCP16301 Cuk-based LED driver demonstration
- 300 mA constant current source
- Input operating voltage from 6–18 Vdc

MCP1630 Boost Mode LED Driver Demonstration Board (MCP1630DML-LED2)

- MCP1630 Boost LED driver demo
- 350 or 700 mA constant current source
- Input operating voltage range of 9–16 Vdc
- Maximum power output of 30W

MCP1631HV Digitally Controlled Programmable Current Source Reference Design (MCP1631RD-DCCP1)

- MCP1631 SEPIC LED driver demonstration
- Input voltage range of 3.5–16 Vdc
- Maximum power output of 8.5W

MCP1650 Multiple White LED Demonstration Board (MCP1650DML-LED2)

- MCP1650 Boost LED driver demo
- Nine LED string in series
- PIC10F202 controlled
  - Enable control of MCP1650
  - Push-button input for LED intensity adjustment

MCP1252 Charge Pump Backlight Demonstration Board (MCP1252DML-BKLT)

- LED backlighting demonstration
- MCP1252 evaluation platform
- Light intensity controlled via ballast resistors

- PIC10F206 controlled
  - Enable control of MCP1252
  - Push-button input for LED intensity adjustment

Digital LED Lighting Development Kit (DM330014)

- 100% digitally controlled LED driver
- Fully controlled with a single dsPIC33FJ16GS504 DSC
- RGB LED driver with DMX512 support for brightness control
- Dimming and color hue control
- Flexible input voltage support, including buck and boost topologies
- Fully dimmable, full digital control, Fault protection
- Advanced features implemented in software

MCP1650 3W White LED Demonstration Board (MCP1650DML-LED1)

- MCP1650 Boost LED driver demonstration
- Nine LED string in series
- PIC10F202 controlled
  - Enable control of MCP1650
  - Push-button input for LED intensity adjustment
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Collaborative Partners

To ensure the development of the most innovative lighting solutions, Microchip works with industry leaders to collaborate on various reference designs, demonstrations, and development tools. Creating the most effective lighting solution requires products—from integrated circuits, to light sources, optics, thermals and mechanics—expertise and services from a multitude of sources.

<table>
<thead>
<tr>
<th>Collaborative Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CREE</strong></td>
</tr>
<tr>
<td>Cree, Inc leads the industry through performance and application optimized lighting-class LEDs that simplify design and lower system costs to obsolete energy-wasting traditional lighting. Cree’s relentless innovation drives the LED lighting revolution with products designed to accelerate LED adoption and push the boundaries of what’s possible with LED lighting. Cree’s LED product families include XLamp® and High Brightness LEDs.</td>
</tr>
<tr>
<td><strong>LEDnLIGHT</strong></td>
</tr>
<tr>
<td>LEDnLIGHT optics are made by Gaggione SAS the—Montréal La Cluse, France, plastic optics manufacturer—who produces the very narrow beam collimator providing excellent color mixing properties to address stage lighting, entertainment lighting and architectural lighting applications, to name a few. Gaggione is an ISO 9001 and ISO TS 16949 certified company and a leader in producing solutions using polymers for customers around the world. The company provides comprehensive design, development and manufacturing capabilities for the production of standardized and customized polymer optics at their state-of-the-art production technologies and facilities in France, Switzerland and Canada.</td>
</tr>
<tr>
<td><strong>LUMVATECH</strong></td>
</tr>
<tr>
<td>Lumvatech is a cutting-edge manufacturer of LED light panels and complete backlighting solutions. Lumvatech specializes in thin and flexible applications. From light panels to complete interactive capacitive touch solutions, Lumvatech manufactures a wide variety of standard or custom products and solutions.</td>
</tr>
<tr>
<td><strong>Airspeed</strong></td>
</tr>
<tr>
<td>An experienced provider of innovative product solutions, Airspeed specializes in the design and manufacturing of complete mechanical packages. The company’s many years of experience in plastics, metal fabrication, die cast, cable assemblies and global logistics management ensures that customers can offer the most competitive product to the market.</td>
</tr>
<tr>
<td><strong>Energizer Holdings, Inc.</strong></td>
</tr>
<tr>
<td>Energizer Holdings, Inc., headquartered in St. Louis, MO, is one of the world’s largest manufacturers of primary batteries, portable flashlights and lanterns. Energizer® Ultimate Lithium batteries deliver long-lasting power to keep up with today’s high-tech devices like digital cameras, LED flashlights and handheld GPS devices.</td>
</tr>
</tbody>
</table>
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