Most switching power supplies are designed with closed-loop feedback circuitry to provide stable power under various transient and load conditions. The feedback methodology options fall into two general categories, voltage mode control (VMC) and current mode control (CMC). Both methodologies have their strengths and weaknesses that determine the appropriate selection for the end–equipment application.

### Control Methodologies

**Voltage mode control** utilizes a scaled value of the output voltage as the feedback signal. This methodology provides simple, straightforward feedback architecture for the control path. However, this method has several disadvantages that should be noted. The most significant disadvantage is output voltage regulation requires sensing a change in output voltage and propagation through the entire feedback signal and filter before the output is appropriately compensated. This can generate a unacceptably slow response for systems that desire high levels of regulation. The feedback compensation of the supply requires a higher level of analysis to address the two poles introduced by the output low–pass filter. Additionally, the feedback component values must be adjusted since different input voltages affect the overall loop gain.

Current mode control addresses the above short-falls of voltage mode control by using the inductor current waveform for control. This signal is included with the output voltage feedback loop as a second, fast response control loop. The additional feedback loop does potentially increase the circuit/feedback complexity, so the advantages need to be evaluated as part of the design requirements.

By using the inductor current as part of the feedback control:

1. The added current feedback loop responds faster compared with only using the output voltage for feedback control. Additionally, with the inductor current information, the circuit can be designed to provide pulse by pulse current limiting allowing rapid detection and control for current limiting needs.

2. The power supply looks like a voltage controlled current source. This permits a modular supply design to allow load sharing between multiple supplies in a parallel configuration.

3. The effects of the inductor in the control loop can be minimized since the current feedback loop effectively reduces the compensation to a single pole requirement.

While current mode control addresses some of the drawbacks of VMC, it introduces challenges that can effect the circuit performance. The addition of the current feedback loop increases the complexity of the control/feedback circuit and circuit analysis. Stability across the entire range of duty cycles and sensitivity to noise signals are other items that need to be considered in the selection of current mode control.

CMC can further be broken down into several different types of control schemes: peak, valley, emulated, hysteretic, and average CMC. The below text discusses the two most common methodologies used in circuit design — peak and average current mode control.

### Peak Current Mode Control

Peak current mode control (PCMC) utilizes the current waveform directly as the ramp waveform into the PWM–generation comparator instead of an externally generated sawtooth– or triangle–signal like VMC. The upslope portion of the inductor current or high–side transistor current waveform is used to provide a fast response control loop in addition to the existing voltage control loop. As shown in Figure 1, the current signal is compared with the output of the voltage error amplifier to generate the PWM control signal for the power supply.

![Figure 1. Block Diagram of PCMC circuit](image-url)
Switching power supplies provide high levels of efficiency between the input and output power rails. To maintain the high efficiency of the converter, ideally the sense resistor used to measure the inductor current is as small as possible to reduce power loss due to the measurement. This small–valued resistor results in a small amplitude feedback signal. Since the inductor current waveform is used directly as the comparator input signal, PCMC is known to be susceptible to noise and voltage transients. Using a current sense amplifier like the INA240 with high common-mode rejection ratio (CMRR) provides suppression of transients associated with pulse-width modulation (PWM) signals and systems. The gain flexibility of the INA240 allows the inductor current waveform be amplified to provide a larger signal for comparison without the need for additional gain or sacrificing performance. Additionally, the low offset and gain errors provide a reduction in design variations and changes across temperature. To utilize PCMC, the inductor current necessitates a high common–mode voltage measurement. The INA240 common–mode range allows for a wide range in supply input and output voltages.

It should be noted that PCMC most often adds slope compensation to address stability issues with duty cycles greater than 50%. The slope compensation is added to the inductor current before being used as the comparator input signal.

The noise sensitivity of PCMC methodology is improved using ACMC to acceptable performance levels with the INA240 high CMRR helping to provide additional transient reduction. The INA240 high common–mode range is required to make the inductor current measurement and allows usage of the current amplifier in a wide–range of output voltages. The INA240 high accuracy and low drift specifications provide consistent measurement across temperature and different assemblies.

The INA240 provides performance and features for measurement accuracy which is needed to maintain good control signal integrity. The INA240 features a 25μV maximum input offset voltage and a 0.20% maximum gain error specification at room temperature. Temperature stability is important to maintain system performance and the INA240 provides input offset voltage drift of 250nV/°C with a 2.5ppm/°C amplifier gain drift. The INA240 features enhanced PWM rejection to improve performance with large common-mode transients and a wide common-mode input range for maximum design variance for supply output voltages.

**Alternative Device Recommendations**

Based on system requirements, alternative devices are available that can provide the needed performance and functionality. The LMP8601 family provides lower performance levels than the INA240 for in-line sensing applications. The INA282 allows current measurement for high common-mode voltages, making it ideal for high voltage DC application that do not have PWM signals. The LMP8481 is a bi-directional current sense amplifier used in high common-mode voltage applications that do not require the input voltage range of the amplifier to include ground.

**Table 1. Alternative Device Recommendations**

<table>
<thead>
<tr>
<th>Device</th>
<th>Optimized Parameters</th>
<th>Performance Trade-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>INA253</td>
<td>Integrated Low inductive precision shunt: 2mΩ, 0.1%, Enhanced PWM rejection</td>
<td>+/-15A maximum continuous current at TA = 85°C</td>
</tr>
<tr>
<td>INA282</td>
<td>Low power, High Gain Options, High Supply Voltage</td>
<td>No Enhanced PWM Rejection, Higher drift specifications</td>
</tr>
<tr>
<td>LMP8481</td>
<td>Wide Common–Mode Input Range, Low power</td>
<td>No Enhanced PWM Rejection, Reduced gain options, Common–mode range does not include ground</td>
</tr>
</tbody>
</table>

**Table 2. Adjacent TechNotes**

<table>
<thead>
<tr>
<th>TechNote</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBOA189</td>
<td>Precision Brightness and Color Mixing in LED Lighting Using Discrete Current Sense Amplifiers</td>
</tr>
<tr>
<td>SBOA174</td>
<td>Current Sensing in an H-Bridge</td>
</tr>
<tr>
<td>SBOA176</td>
<td>Switching Power Supply Current Measurements</td>
</tr>
</tbody>
</table>
IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI') technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, “TI Resources”) are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI’s provision of TI Resources does not expand or otherwise alter TI’s applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT. AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED “AS IS” AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI’s standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated