



IN-PLUG[®] series: IPS20 & IPS21

Low-Voltage Current Sensing Precision Feedback Controllers

for **Maximum Efficiency at Any Output Current**

PRELIMINARY – REV3 -

INTRODUCTION

DESCRIPTION

IN-PLUG[®] IPS20 & IPS21 Integrated Circuits are low-voltage current sensing feedback controllers used in Switch Mode Power Supplies to control load-side current and voltage. They have been designed to limit the power dissipated in the sensing circuitry for high output current applications that require current limiting. They also provide excellent loop stability and superb transient response. They both incorporate a 4V shunt regulator for maximum flexibility to power the chip.

The IPS20 and IPS21 only differ by the characteristics of the current sensing references.

The IPS20 incorporates a trimmed 50mV reference with a positive temperature coefficient which closely matches that of a PCB copper trace. This copper trace sensing method can be used inexpensively with very low associated power losses.

The IPS21 incorporates a temperature compensated 100mV reference for more conventional resistors.

Both controllers feature the same voltage regulator section with a trimmed temperature stable voltage reference of 1.19V. This allows the output voltage of the SMPS to be set to any value down to about 1.2V.

The IPS20 and IPS21 are suitable for any SMPS and any make of SMPS controllers, including flyback, forward, PFC and DC/DC solutions.

These flyback controllers work best in complement with the IN-PLUG[®] family of IPS1x flyback controllers, IPS10x PFC controllers and IPS20x Push-Pull controllers.

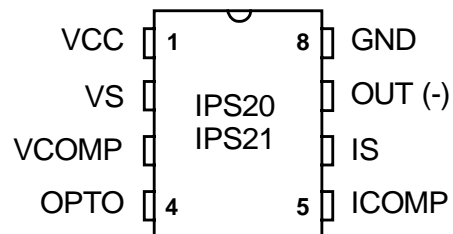
FEATURES

- Dual precision regulators for SMPS voltage and current control
- Output currents up to 50A
- Output voltage down to 1.2V
- 50mV or 100mV current sensing voltage
- 1.20V voltage reference
- Operates with grounded optocoupler
- 4V shunt regulator for VCC supply

APPLICATIONS

- Fast chargers for power tools and other applications
- Battery eliminators
- Industrial and bench-type power supplies
- Distributed power systems

PIN CONFIGURATION: DIP-8 / SOIC-8

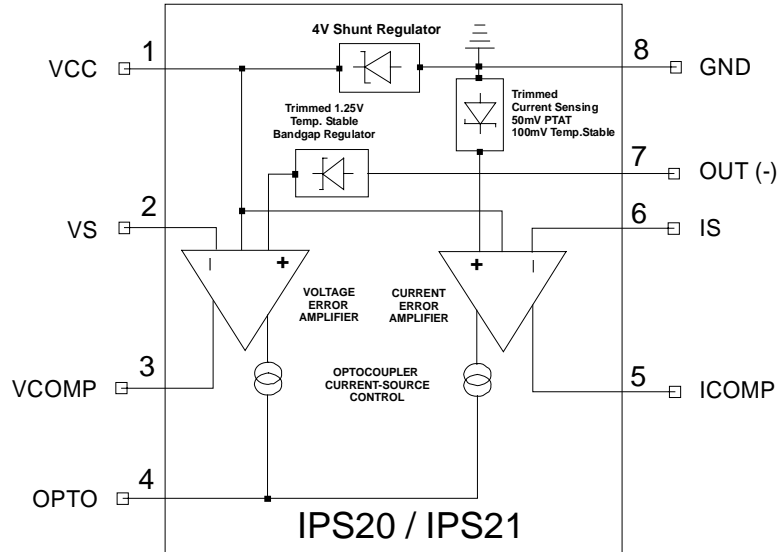


ORDERING INFORMATION

Part No.	ROHS / Pb-Free	Package	Temperature Range	
			Min	Max
IPS20C-D IPS21C-D	-G-LF	8-Pin PDIP	0°C	+70°C Commercial
IPS20I-D IPS21I-D	-G-LF	8-Pin PDIP	-40°C	+85°C Industrial
IPS20C-SO IPS21C-SO	-G-LF	8-Pin SOIC	0°C	+70°C Commercial
IPS20I-SO IPS21I-SO	-G-LF	8-Pin SOIC	-40°C	+85°C Industrial

For detailed ordering information, see page 15

FUNCTIONAL BLOCK DIAGRAM



PIN DESCRIPTION

PIN	Description
1- VCC	IC positive supply pin. The chip behaves like a 4 volt zener diode referenced to GND
2- VS	Voltage sensing pin. This is the inverting input of the voltage error amplifier. The positive input of the amplifier is connected to an internal trimmed 1.20V voltage reference. An external voltage divider connected to this point sets the output voltage. This pin is also used for voltage loop compensation when required.
3- VCOMP	Voltage loop compensation pin. This is the output of the voltage error amplifier. The voltage loop compensation network, when required, is connected between this point and VS pin. Please note that this pin is not a zero-impedance node (1KΩ nominal).
4- OPTO	Optocoupler driver pin. This pin drives an external optocoupler connected to GND. A current-mode drive is used for maximum noise rejection.
5- ICOMP	Current loop compensation pin. (similar to VCOMP) This is the output of the current error amplifier. The current loop compensation network, when required, is connected between this point and the IS pin. Please note that this is not a zero-impedance point (1KΩ nominal).
6- IS	Current sensing pin. This pin is the inverting input of the current sense amplifier. The positive input of the amplifier is connected to an internal trimmed reference. The sensing threshold is 50mV PTAT (IPS20) or 100mV constant (IPS21). This pin should be connected through a resistor to the external current sensing resistor.
7- OUT (-)	Negative output pin. This pin is the negative side of the 1.20V trimmed voltage reference. It should be connected to the negative output of the SMPS.
8- GND	Ground pin. This is the most negative IC pin. The first output decoupling capacitor should return to it. Do not confuse this pin with the IS pin and the OUT(-) pin which are described above.

TYPICAL FEEDBACK CIRCUITRY WITH CONTROL OF PRIMARY FLYBACK CONVERTER

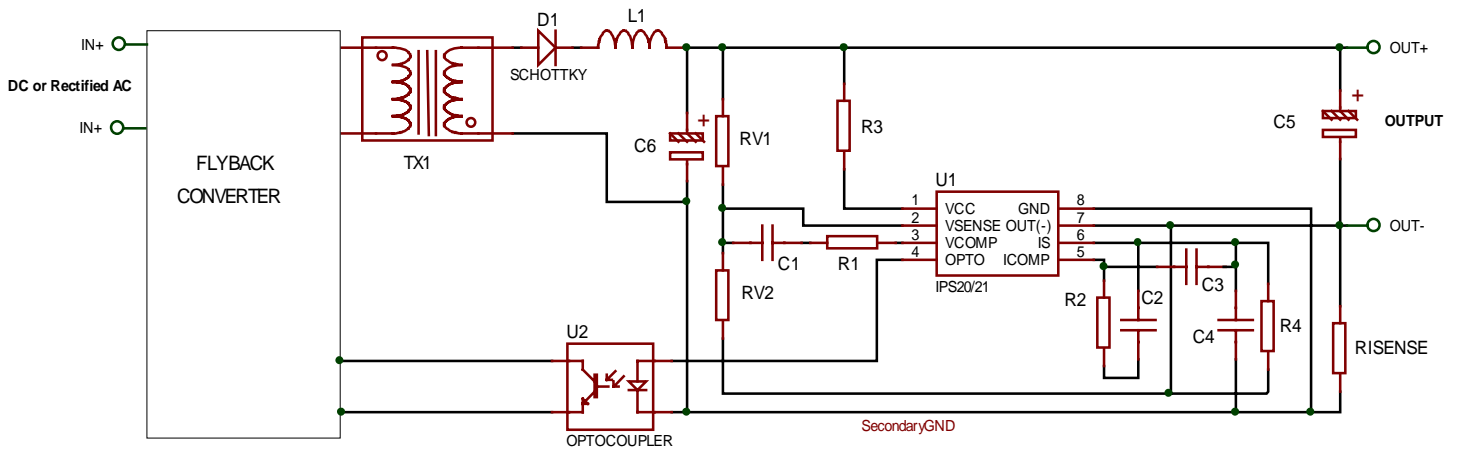


Fig. 1

1) Current limiting:

The current limiting is adjustable through RISENSE

2) Regulated Voltage:

The regulated voltage is adjustable through RV1 and RV2

3) Compensation

The voltage-control trans-conductance operational amplifier can be fully compensated. Both of its compensation pins are directly accessible for external compensation components.

The suitable compensation network is shown in Fig.1. It consists of a capacitor C1 and a resistor R1 in series, connected in parallel with another capacitor C2.

The current-control trans-conductance operational amplifier can be fully compensated. Both of its compensation pins are directly accessible for external compensation components.

The suitable compensation network is shown in Fig.1. It consists of a resistor R2 and a capacitor C2 in series, in parallel with a capacitor C3. Resistor R4 provides the input impedance that the compensation network works with. Capacitor C4, with R4, implements a small amount of filtering.

Determination of V_{out} (Output Voltage):

$$V_{out} = V_{SENSE} \times (RV1 + RV2) / RV2$$

(Nominal VSENSE = 1.19V)

Determination of I_{limit} (Current Limit):

$$I_{limit} = IS \text{ threshold} / RISENSE$$

Nominal IS threshold :

IPS20= 50mV

IPS21= 100mV

IN-PLUG® IPS20 and IPS21

FUNCTIONAL DESCRIPTION

IPS20 and IPS21 are highly integrated feedback solutions for Switch Mode Power Supplies applications requiring constant voltage and constant current mode. They were especially designed to reduce the power dissipated in the load-side current sensing resistor of power supplies with high output current. They provide precise voltage and current regulation that can be fully and independently adjusted. They source the current necessary to drive a ground-referred optocoupler connected to the line side controller.

They both incorporate the same trimmed temperature compensated 1.2V reference to set the output voltage. They only differ by the characteristics of the current sensing references. The IPS20 features a trimmed 50mV reference with a positive temperature coefficient which closely matches that of a PCB copper trace. This copper trace sensing method can be used inexpensively with very low associated power losses. The IPS21 incorporates a constant 100mV reference for more conventional resistors.

Both the output voltage and current sense can be independently adjusted through respectively RV1/RV2 and RISENSE (FIG.1) This information is presented to the IPS20/21 controller, which drives the optocoupler through the OPTO current-mode output pin.

The shunt regulator operates like a zener diode, keeping the chip supply voltage at about 4 volts. At start-up, when the 4 volts are reached, the controller starts normal operation. The overall chip consumption in this case is about 600 μ A.

If the IPS20 or IPS21 Vcc is connected to the converter output voltage, then under start-up or short-circuit conditions, the IPS20/21 isn't supplied with a high enough voltage. This is due to the fact that the chip has its power supply line in common with the power supply line of the system. Therefore, the current limitation can only be ensured by the primary PWM module, that should be chosen accordingly.

If the primary current limitation is considered not to be precise enough for the application, then a sufficient supply for the IPS20/21 has to be ensured under any condition. It would then be necessary to add some circuitry to supply the chip with a separate power line.

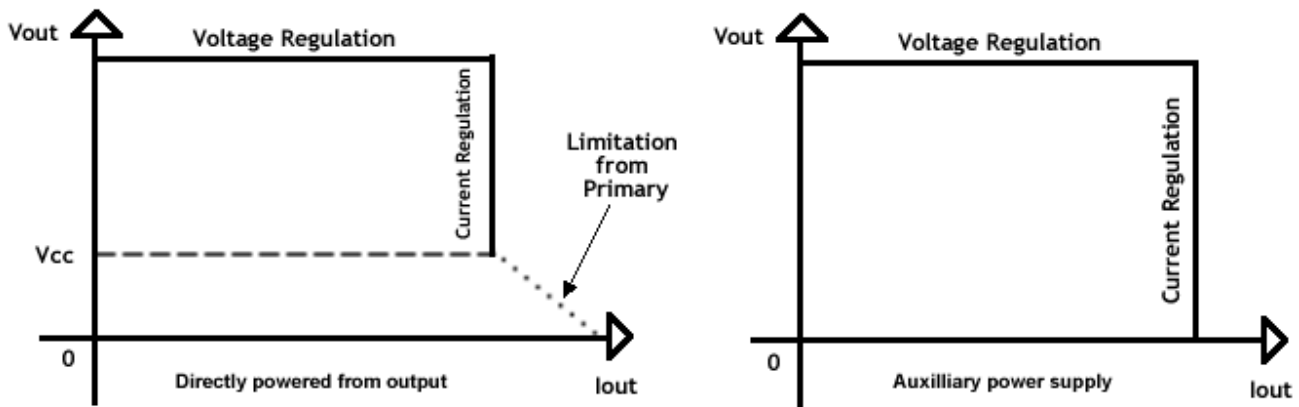
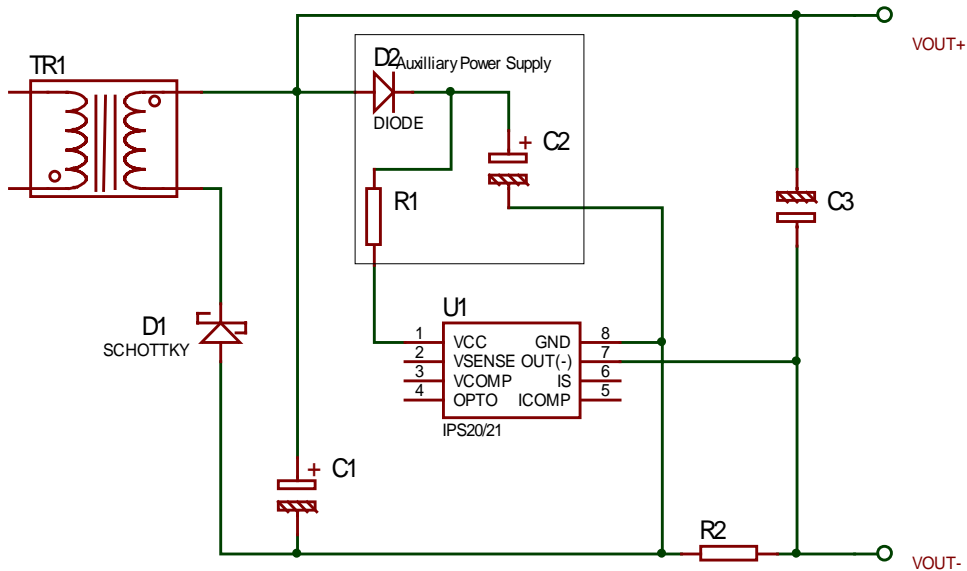


FIG.2 OUTPUT VOLTAGE VERSUS OUTPUT CURRENT

The schematic in Figure 3 below shows how to realize a low-cost power supply for the IPS20/21 (with no additional winding). Please pay attention to the fact that in the particular case presented here, this low-cost power supply can reach voltages as high as twice the voltage of the regulated line.

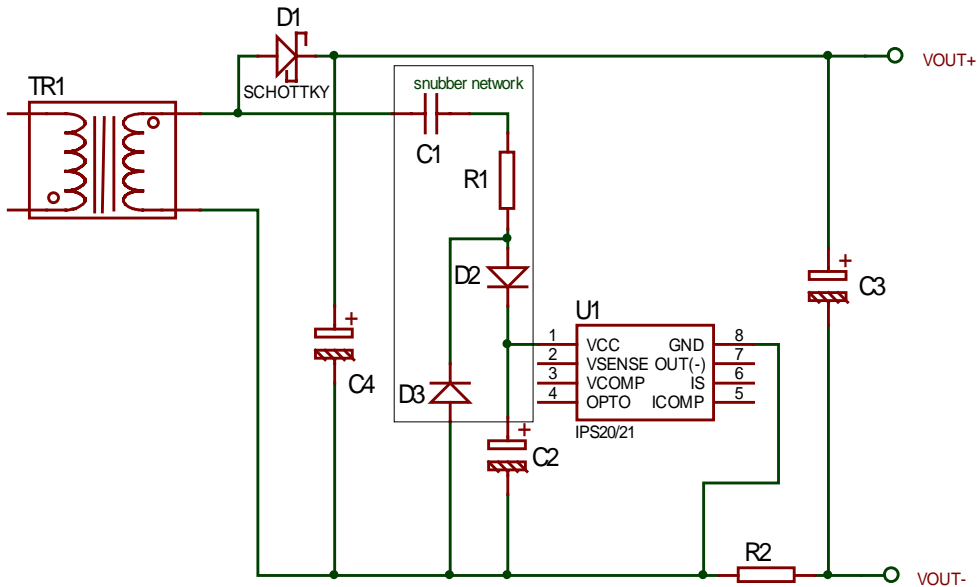
AUXILLIARY POWER SUPPLY

This simple circuitry allows to supply the chip with a separate power line. In case of short-circuit, when $V_{out+} < V_{cc}$, the chip still keeps working properly and limits the output current to its maximum targeted value.



DERIVATIVE OF AAI's PATENTED SNUBBER NETWORK

This technique powers the feedback controller under all circumstances including short-circuits and is especially suitable for flyback, PFC and forward converters.



ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATING		
Characteristics	Value	UNITS
IPS 20 and IPS21 Max I _{CC} (4V shunt regulator)	140	mA
Opto sourcing current with external resistor	20	mA
Operating junction temperature	- 40 to 150	°C
Storage temperature range	- 55 to 150	
Lead temperature (3 mm from case for 5 sec.)	260	

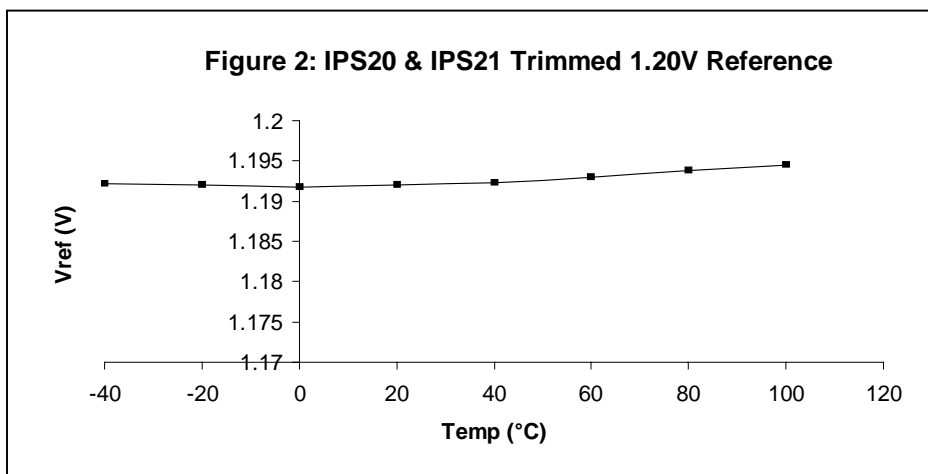
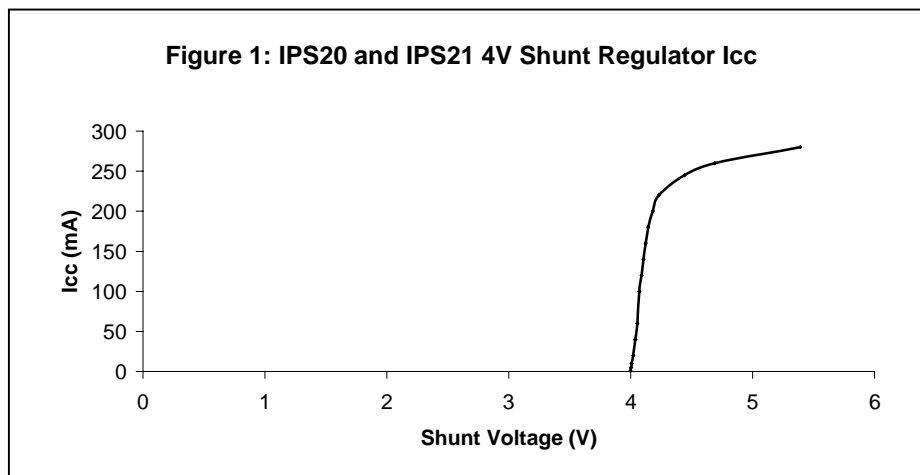
PARAMETER	TEST CONDITIONS	PARAMETERS			UNITS
		MIN.	TYP.	MAX.	
Supply, Bias					
Shunt regulator voltage	I _{CC} = 1 to 30 mA	3.8	4	4.2	V
Shunt regulator dynamic resistance (see figure 1)	1 to 50 mA	-	1	3	Ω
Shunt regulator max peak repetitive current		-	100	-	mA
Min I _{CC} to ensure operation (internal current)		-	-	600	μA
Voltage Regulation					
VSENSE threshold (note1)	I _{OPTO} = 500 μA Z _{in} =10KΩ	1.17	1.19	1.21	V
VSENSE threshold variation with temperature	I _{OPTO} = 500 μA, -40°C to +85°C (see figure 2)	-	+/- 3	+/- 6	mV
Output impedance of VCOMP		-	1	-	KΩ
Voltage gain to VCOMP	(see figure 7)	-	115	-	dB
Unity gain bandwidth	(see figure 7)	-	500	-	KHz
Phase margin in unity gain		-	82	-	Degrees
VSENSE Input current		-	-	0.6	μA
Transconductance from VSENSE to OPTO	@ V _{CC} = 2.5V (see figure 5)	-	4	-	mA/mV
Max OPTO output sourcing current without ext. resistor	@ V _{CC} = 5V (see figure 5)	1.2	-	-	mA
Max OPTO output sourcing current with ext. resistor	@ V _{CC} = 2.5V (see figure 3)	10	-	-	mA
Current Limiting					
ISENSE threshold (IPS20)	I _{CC} = 1 mA (see figure 3)	49	50	51	mV
ISENSE threshold variation with temperature (IPS20)	I _{CC} = 1 mA, -40°C to +85°C (see figure 3)	-	0.16	-	mV /°C
ISENSE threshold (IPS21)	I _{CC} = 1 mA (see figure 4)	97	99	101	mV
ISENSE threshold variation with temperature (IPS21)	I _{CC} = 1 mA, -40°C to +85°C (see figure 4)	-	3	-	μV/°C
Output impedance of ICOMP		-	1	-	KΩ
Voltage gain to ICOMP	(see figure 8)	-	138	-	dB

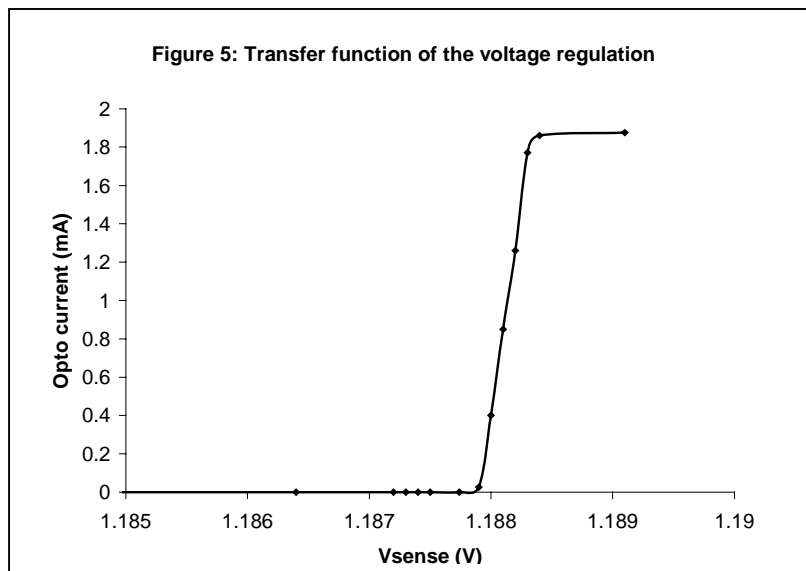
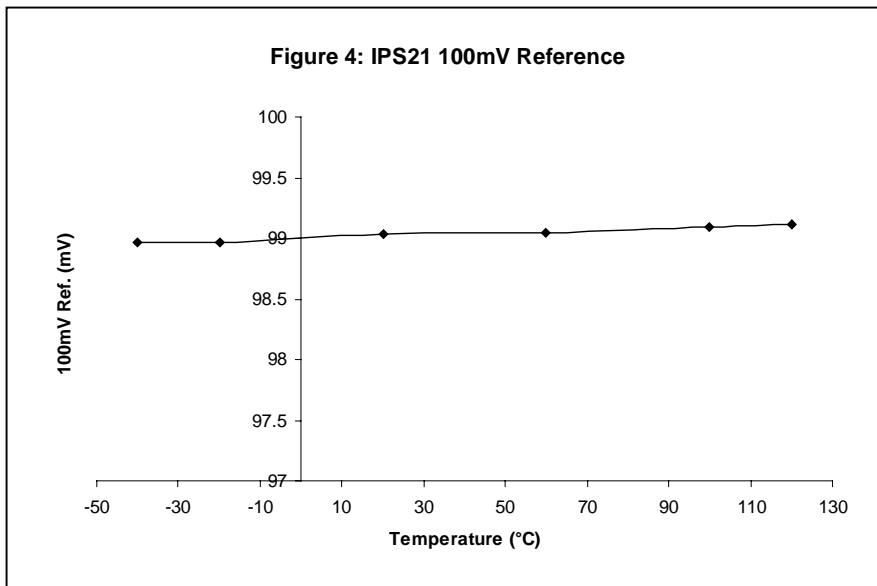
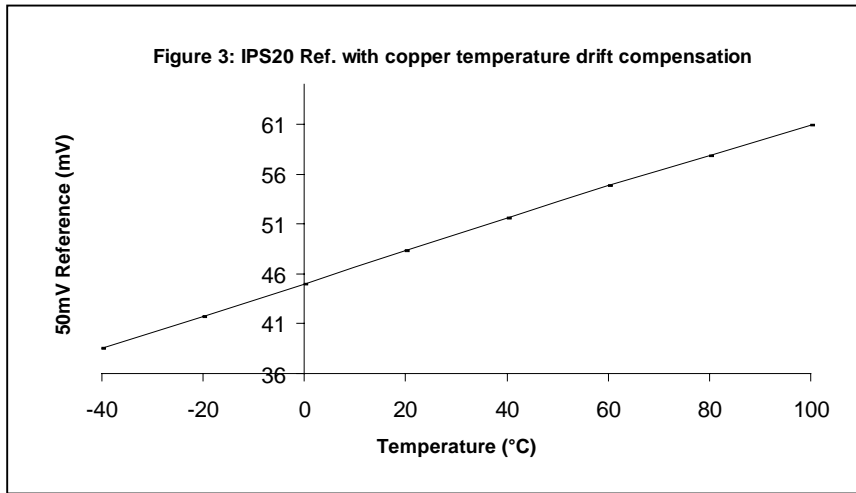
Unity gain bandwidth to ICOMP	(see figure 8)	-	2	-	MHz
Phase margin in unity gain		-	54	-	Degrees
ISENSE Input current		-	-	+/-50	nA
Transconductance from ISENSE to OPTO	(see figure 6a & 6b) IPS20: 6a, IPS21: 6b	-	60	-	mA/mV
Max OPTO output sourcing current without ext. resistor	@ $V_{CC} = 1.30V$ (see figure 5)	1.2	-	-	mA
Max OPTO output sourcing current with ext. resistor	@ $V_{CC} = 2.5V$ (see figure 5)	10	-	-	mA

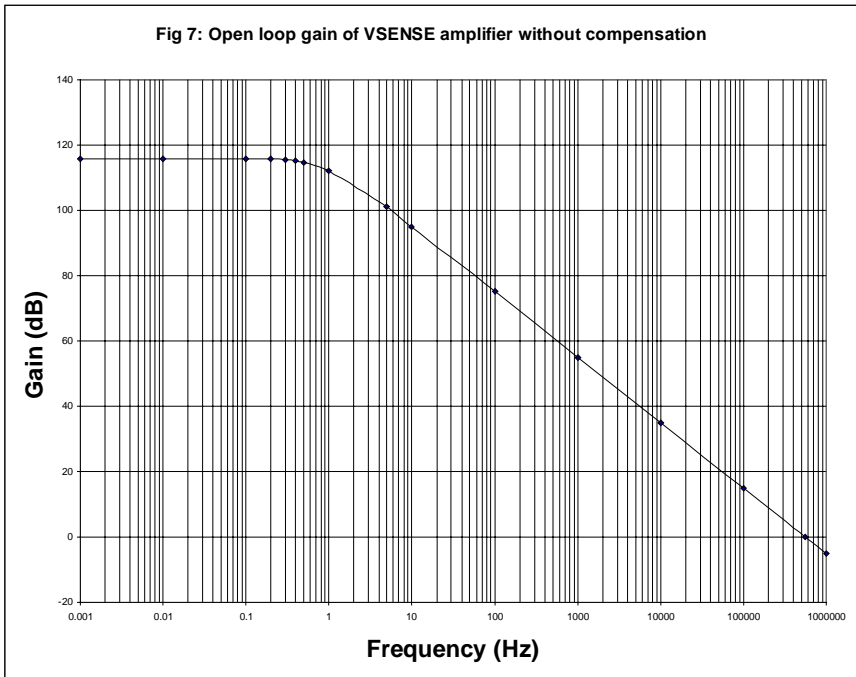
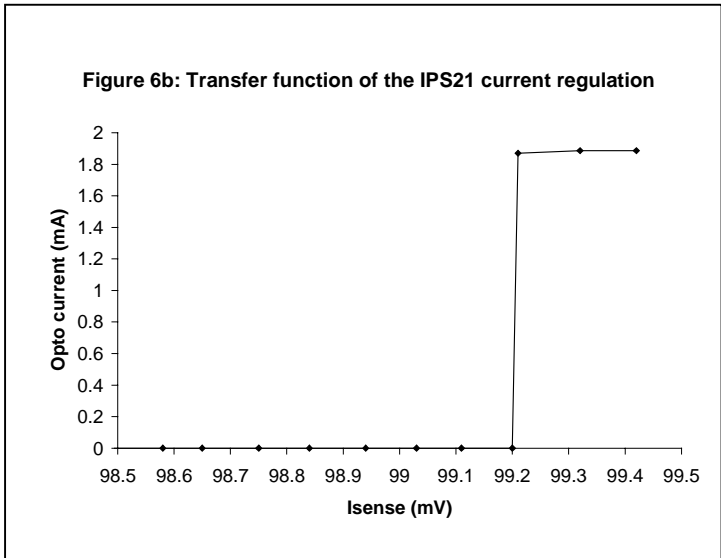
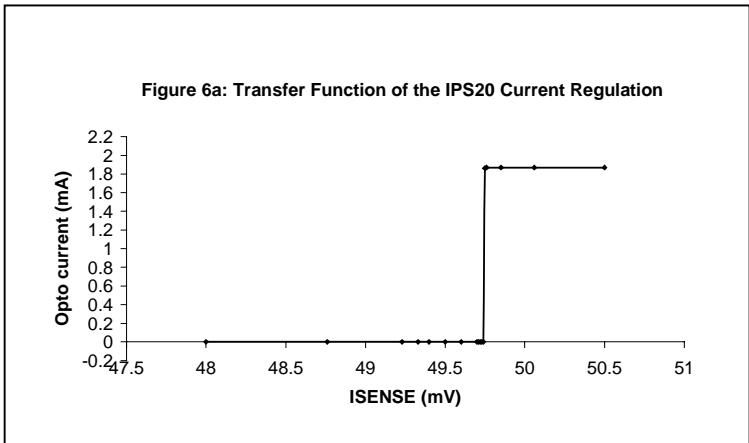
Note1: Tighter tolerances to 0.5% available upon request.

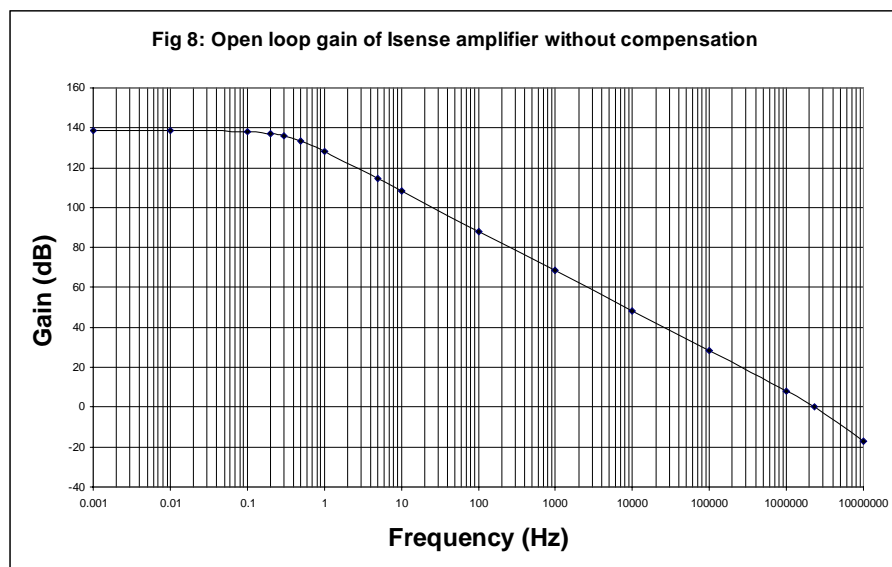
Note2: All values are @ 25°C unless otherwise specified.

Note3: Electrical parameters, although guaranteed, are not all 100% tested in production.









Application Information

The IPS20 and IPS21 chips are intended for use as voltage feedback control and current limiting on the secondary side of switching power supplies.

Powering the chip (Pin1 -VCC and Pin 8 - GND)

The VCC pin acts like a 4 volt zener. This is a different chip-power concept than the IPS25, a self-powered feedback controller, optimized for output currents below 1A (see IPS25 datasheet for details). The GND pin is the lowest voltage the chip sees. What this means is that in a typical “positive output voltage with current sense resistor” application, the GND pin DOES NOT go to the negative output pin of the power supply, rather it goes to the “transformer side” of the current-sense resistor. No input voltage should be greater than VCC or less than GND. It is recommended as good engineering practice to have a decoupling capacitor from VCC-to-GND of 10uF. The intended design implementation for powering the chip is to have a resistor from VCC to either the output voltage or a separate supply. This resistor should be sized such that at minimum supply voltage (and subtracting 4 volts for the VCC voltage), there is enough current to operate the chip (3mA) plus supply the optoisolator.

Tips for lab experiments

The IPS20/21 are fabricated in a low-voltage IC process (lower than the IPS25). This means that they can be damaged with pin voltages greater than 7 volts. When testing designs using an IPS20/21, it is typical to perform debug with a laboratory current-limited external power supply attached to the VCC pin. This external supply should be set for around 5 volts and 10 milliamps. It is possible to damage an IPS20/21 if one of these lab supplies is set for (say) 12 volts and 10 milliamps, the lab supply is powered-on, and then the lab supply is connected to the IPS20/21, because the VCC voltage will be 12 volts (in this example) until the IPS20/21 starts conducting current and discharges any output capacitance in the lab supply.

Note that the overcurrent performance of a power supply using an IPS20/21 will be different based on whether the chip is powered by the output (where the VCC supply will be collapsing) versus from an independent supply. The user should be sure to check that the output voltage and current characteristics during overcurrent conditions meet his/her specific needs. During startup and short-circuit conditions, the IPS20/21 may not have enough supply voltage to operate. In this situation, the output current limitation must come from the primary side PWM module, and must be designed accordingly.

VSENSE (Pin 2), VCOMP (Pin 3)

The internal voltage reference for voltage feedback is 1.19 volts. The output voltage being sensed/regulated should have a voltage divider to 1.19 volts connected to pin 2. For good voltage feedback loop performance, no capacitor should be connected from pin 2 to ground. The recommended series-RC component values from pin 2 to pin 3 to roll-off the loop gain are 10k ohms and 68nF.

OPTO (Pin 4)

The OPTO pin is a current source (unlike a shunt regulator like the TL431, which is a current sink). The intended connection for the voltage feedback network is to connect the OPTO pin to the anode of the photodiode in an optoisolator, with the cathode of the photodiode connected to ground. The IPS20/21 use very little current to operate, but the user is reminded that the OPTO current being sourced comes through the VCC pin.

ICOMP (Pin 5) and IS (Pin 6)

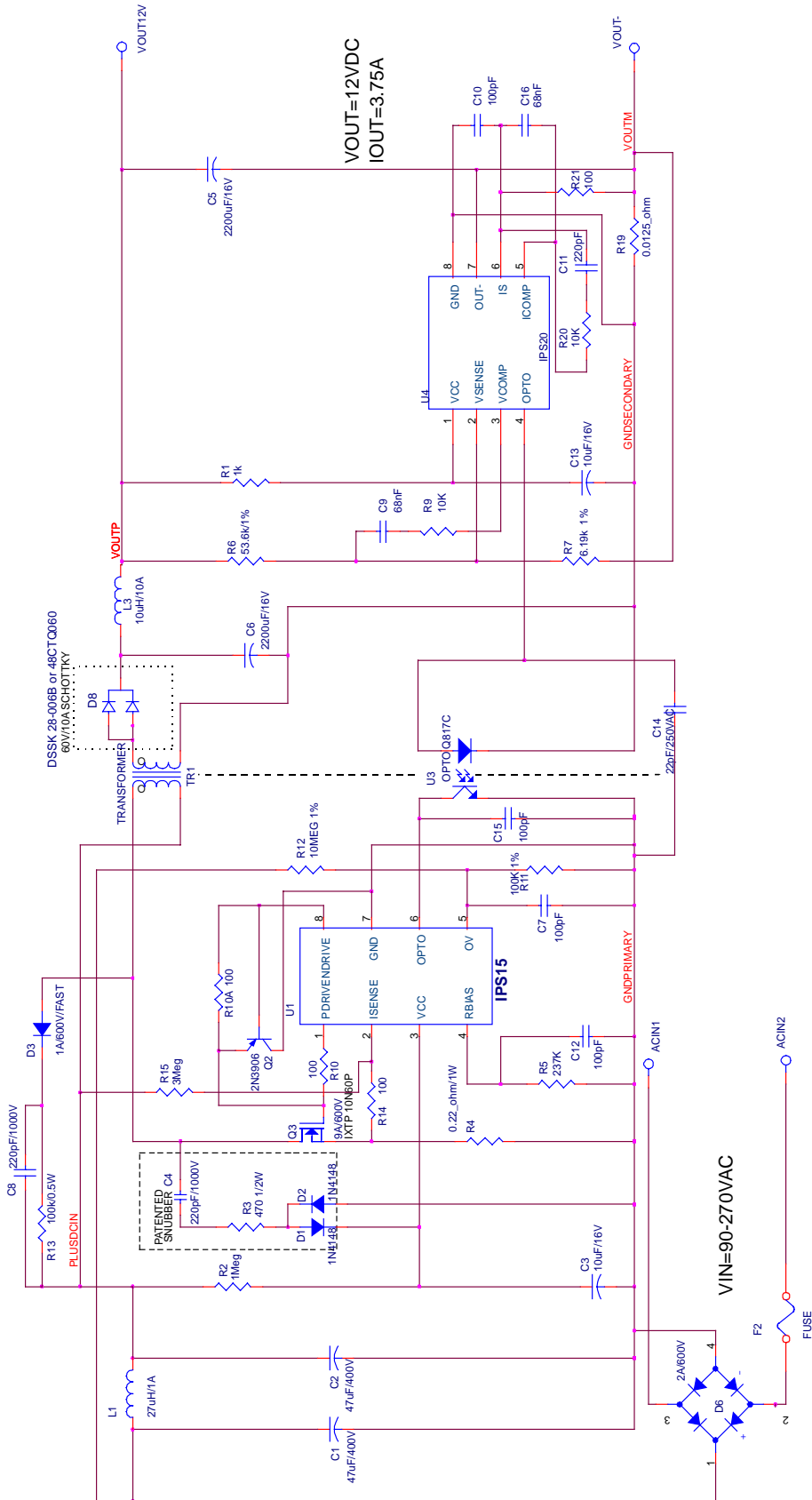
The current sense resistor connects between IS and GND. For a positive output power supply, IS is the negative output pin. The internal voltage reference for current limiting (50 millivolts for IPS20, 100 millivolts for IPS21) is referenced to GND. The recommended component values from pin 5 to pin 6 to roll-off the loop gain are a series 10k ohms and 220pF, in parallel with 68nF. To reduce susceptibility to noise spikes, an additional RC filter network might be desirable from IS to GND (refer to the Typical Application Schematic Figure 1 above).

OUT(-) (Pin 7)

The negative side of the internal voltage reference for voltage feedback is connected here. For a typical application with a positive output voltage and a current sense resistor, this pin connects to the more-negative pin of the output voltage. This configuration allows the voltage feedback to compensate for the voltage drop across the current sense resistor (which will vary with load).

IN-PLUG® IPS20 & IPS21 Preliminary Datasheet - Rev3 - Voltage / Current Feedback Controllers

IPS-45DK1525: 45W (12V - 3.75A) APPLICATION USING IPS20/21 and IPS15



45 WATT DESIGN DESCRIPTION/METHODOLOGY

The demo board for the IPS20/21 is a 45 watt flyback power supply, taking in AC line voltage and outputting 12VDC. The important parameters are:

VINmin = 85 VAC

VOUT = 12 VDC

IOUTmax = 3.75 A

Freq = 60 kHz

Discontinuous-mode

This demo board will operate using either the IPS20 or the IPS21. The only difference between the two applications is the current sense resistor (reference designator R19 on the board). For the IPS21, a current sense resistor with constant resistance is chosen, with the resistor value chosen based on the IPS21 100mV threshold. $0.1\text{V}/3.75\text{A} = 26$ milliohms maximum value (25 milliohms is chosen as the nearest standard value). In a similar manner, for the IPS20, with a 50 millivolt threshold, a resistance of 12.5 milliohms is desired. The bottom side of the demo board has a narrow trace underneath resistor R19. This trace is intended to take the place of a discrete resistor. The intended way of using this is to remove the discrete R19 and solder a very short wire jumper between the two adjacent pads on the bottom side.

POWER STAGE

The design approach is to focus on the worst-case (minimum input voltage, maximum load). The first equation is based on input power (assuming 70% efficiency), where L is the primary inductance, I is the peak current in the primary, and f is frequency.

$$P = 0.5 * L * I^2 * f = 45 = 0.7 * 0.5 * L * I^2 * 60k$$

Then, an operating point is chosen (50% duty cycle at minimum input voltage), and the current ramp (where V is the DC bus voltage and t is time) becomes:

$$V = L * I / t = 85 * \sqrt{2} = L * I / (1/2 * 60k)$$

These two equations are solved simultaneously for L and I to give 470uH and 2.1 amps.

A core/bobbin combo is chosen (PQ2620, Ae = 119 sq.mm, Aw = 30.7 sq. mm, Bs at = 0.2 tesla) based on the operating power and frequency. The primary turns are derived from $L * I = N_p * A_e * B$, Np is 42. The secondary turns are derived from the output voltage and a target of 100V of reflected voltage, $V_s * N_p / N_s = V_{refl}$, Ns is 5. The wire gage is determined by allocating half the winding window to the primary and half to the secondary (primary uses 23 AWG, secondary uses 13 AWG). To make the transformer easier to build, the secondary wound trifilar (three parallel strands of 19 AWG). A copy of the transformer specification is available from AAI Marketing on request.

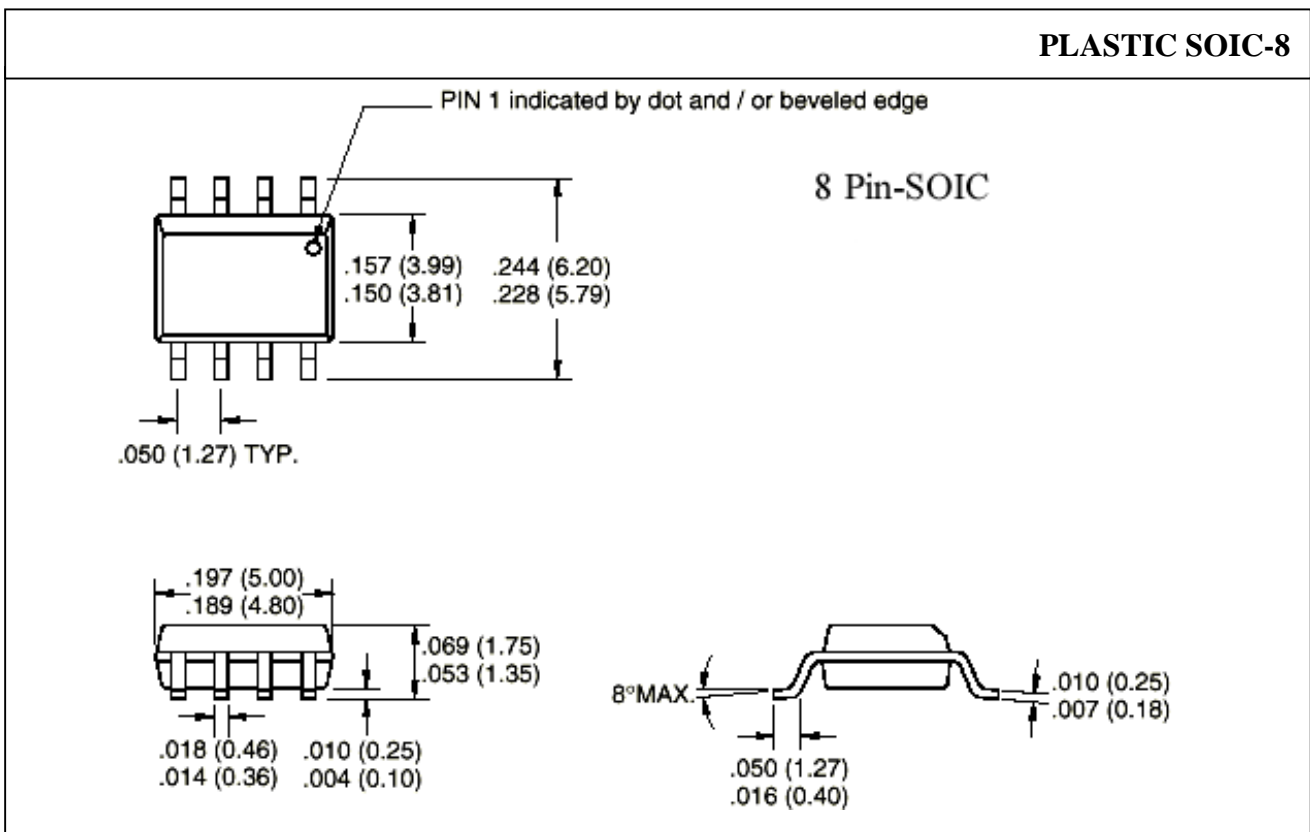
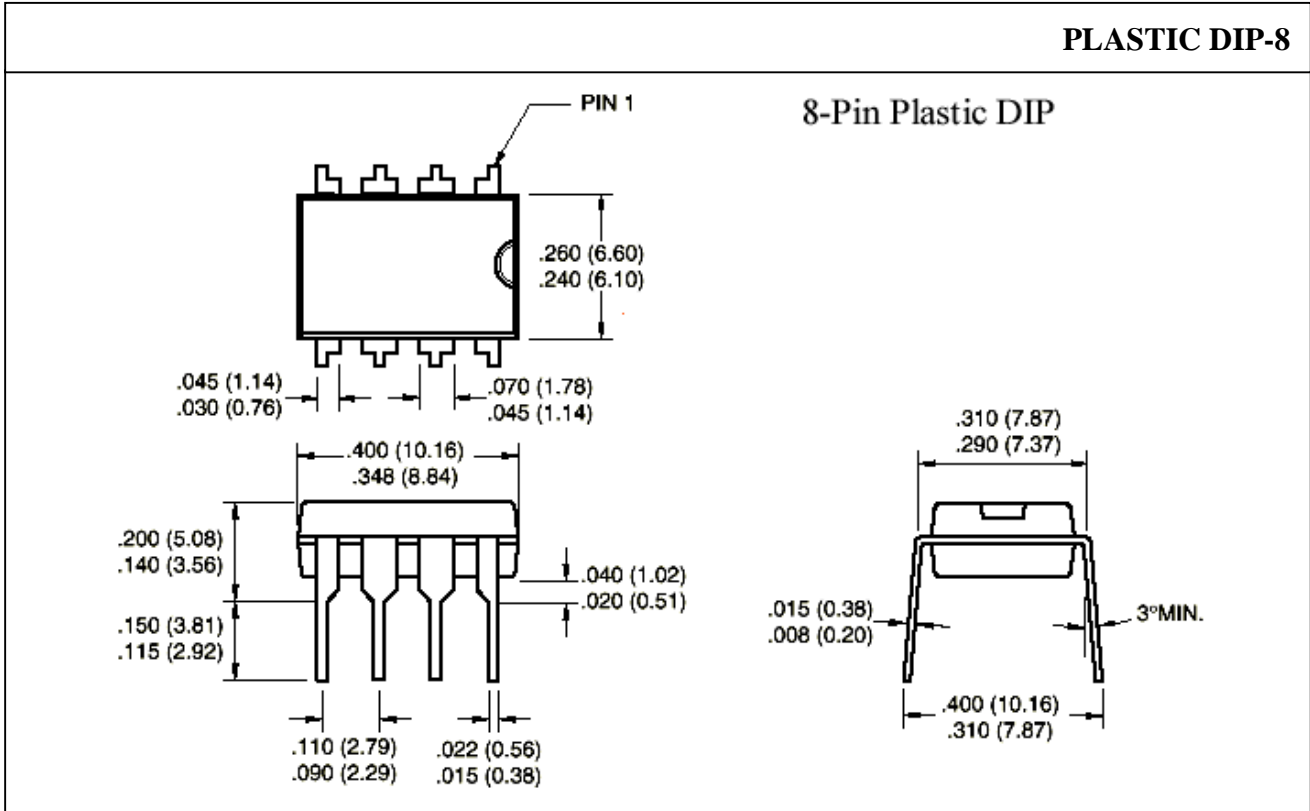
SECONDARY COMPONENTS

The voltage divider to the VSENSE pin was chosen to divide the 12 volt output to 1.19 volts (the internal voltage reference). The bottom resistor was chosen as 6.19k (this sets the sense current to $1.19/6.19 = 200$ microamps) and the top resistor becomes 56.2k ($12 * 6.19 / (6.19 + 56.2) = 1.19$). The current sense resistor is set by the output current and current sense voltage. For the IPS20 (a 50 millivolt internal reference), $R = 50 \text{ millivolts} / 4 \text{ amps} = 12.5$ milliohms. The VCOMP series RC was chosen to have a frequency a modest amount greater than the 120 Hz input ripple [$1 / (2 * \pi * 10k * 68nF) = 234 \text{ Hz}$]. The ICOMP components [series RC + parallel C] were chosen to allow high DC gain with continuous roll-off of the frequency response above about 1Hz (the fastest the current sensing needs to respond). The ISENSE amplifier has a gain of 138 dB, so the half power gain will be 135 dB, which is 5.6 Meg. The low frequency pole where the gain ($Z_{feedback} / Z_{in} = [1 / (2 * \pi * 68n * \text{freq})] / 100$) equals 5.6M is 0.47 Hz. The series RC (10k + 220 pF) feedback compensation is not necessary in most designs (it is shown for compatibility with our IPS25 and IPS22/23 feedback controllers).

PRIMARY CONTROL

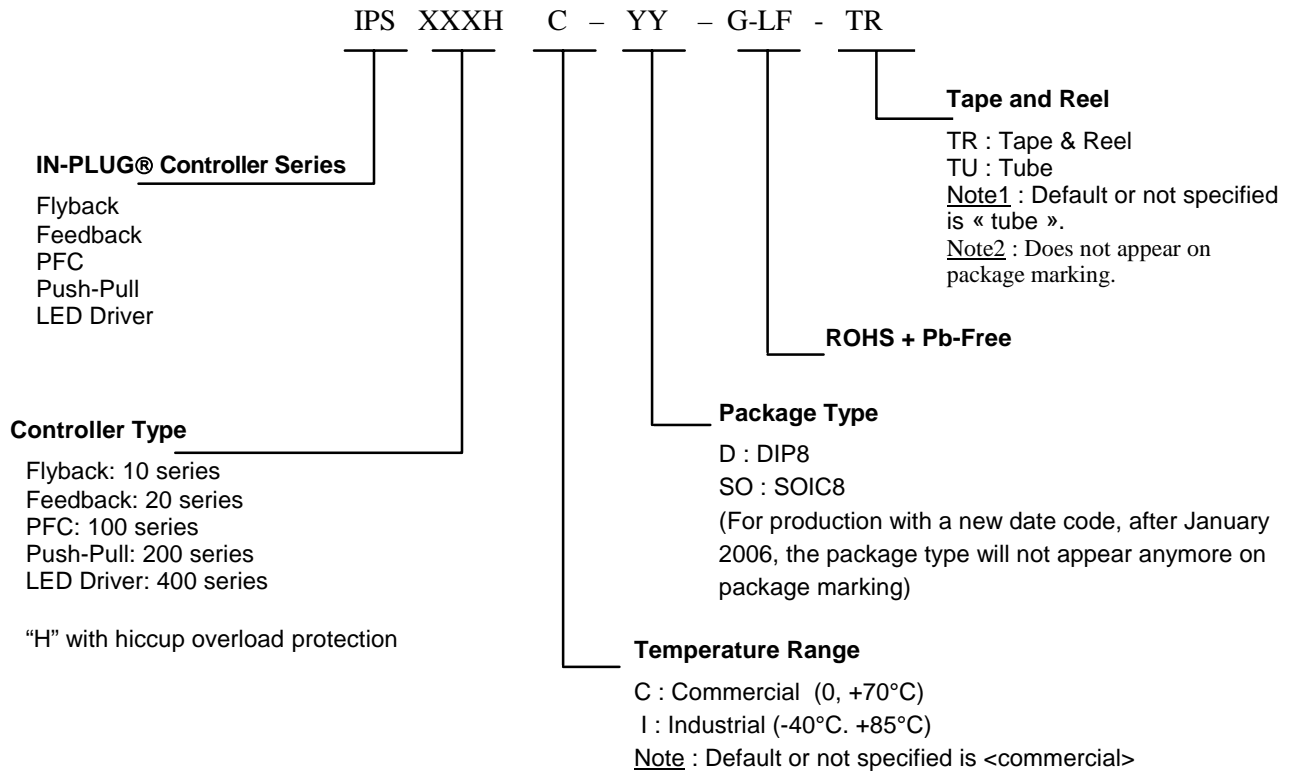
Please refer to the IPS15 datasheet for information about the components surrounding the PWM chip. This design is sufficiently high in power that a discrete snubber was added to the primary in addition to the patented snubber used to power the PWM chip.

PACKAGE DIMENSIONS



ORDERING INFORMATION

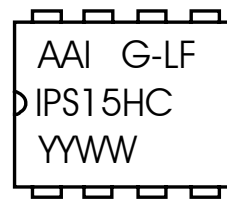
Part-Number



Example of Marking



Non-Green Package



Green ROHS + Pb-Free Package

(Note : For production with a new date code, since January 2006, the package type does not appear anymore on package marking)

This ordering information is for commercial and industrial standard IN-PLUG® controllers ONLY. For custom controllers or for automotive and military temperature ranges, call AAI's sales representative.

IN-PLUG® IPS20 & IPS21 Preliminary Datasheet - Rev3 - Voltage / Current Feedback Controllers

The following is a brief overview of certain terms and conditions of sale of product. For a full and complete copy of all the General Terms and Conditions of Sale, visit our webpage <http://www.asicadvantage.com/terms.htm>.

LIMITED WARRANTY

The product is warranted that it will conform to the applicable specifications and be free of defects for one year. Buyer is responsible for selection of, use of and results obtained from use of the product. Buyer indemnifies and holds ASIC Advantage, Inc. harmless for claims arising out of the application of ASIC Advantage, Inc.'s products to Buyer's designs. Applications described herein or in any catalogs, advertisements or other documents are for illustrative purposes only.

CRITICAL APPLICATIONS

Products are not authorized for use in critical applications including aerospace and life support applications. Use of products in these applications is fully at the risk of the Buyer. Critical applications include any system or device whose failure to perform can result in significant injury to the user.

LETHAL VOLTAGES

Lethal voltages could be present in the applications. Please comply with all applicable safety regulations.

INTELLECTUAL PROPERTY RIGHTS AND PROPRIETARY DATA

ASIC Advantage, Inc. retains all intellectual property rights in the products. Sale of products does not confer on Buyer any license to the intellectual property. ASIC Advantage, Inc. reserves the right to make changes without notice to the products at any time. Buyer agrees not to use or disclose ASIC Advantage Inc.'s proprietary information without written consent.

TRADEMARKS AND PATENTS

- IN-PLUG® is a registered trademark of ASIC Advantage, Inc.
- AAI's modified snubber network is patented under the US Patent # 6,233,165. IN-PLUG® Customers are granted a royalty-free licence for its utilization, provision the parts are purchased factory direct or from an authorized agent.

PROTECTION FOR CUSTOM IN-PLUG® SOLUTIONS

When AAI accepts to design and manufacture IN-PLUG® products to Buyer's designs or specifications, buyer has certain obligations to provide defense in a suit or proceeding claiming infringement of a patent, copyright or trademark or for misappropriation of use of any trade secrets or for unfair competition.

COMPLIANCE WITH LAWS

Buyer agrees that at all times it will comply with all applicable federal, state, municipal, and local laws, orders and regulations. Buyer agrees to comply with all applicable restrictions on exports and re-exports including obtaining any required U.S. Government license, authorization, or approval. Buyer shall pay any duties, levies, taxes, brokerage fees, or customs fees imposed on the products.

TITLE AND DELIVERY

All shipments of goods shall be delivered ExWorks, Sunnyvale, CA, U.S.A. Title in the goods shall not pass to Buyer until ASIC Advantage, Inc. has received in full all amounts owed by Buyer.

LATEST DATASHEET UPDATES

For the latest datasheet updates, visit our web page: <http://www.in-plug.com/datasheets.htm>.

WORLDWIDE REPRESENTATIVES

To access AAI's list of worldwide representatives, visit our web page <http://www.in-plug.com/representatives.htm>

COPYRIGHTS

Copyrights and all other proprietary rights in the Content rests with ASIC Advantage Inc. (AAI) or its licensors. All rights in the Content not expressly granted herein are reserved. Except as otherwise provided, the Content published on this document may be reproduced or distributed in unmodified form for personal non-commercial use only. Any other use of the Content, including without limitation distribution, reproduction, modification, display or transmission without the prior written consent of AAI is strictly prohibited. All copyright and other proprietary notices shall be retained on all reproductions.

ASIC Advantage INC.

1290-B Reamwood Ave, Sunnyvale California 94089, USA

Tel: (1) 408-541-8686 Fax: (1) 408-541-8675

Websites: <http://www.in-plug.com> - <http://www.asicadvantage.com>