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# IN-PLUG<sup>®</sup> series: IPS20 and IPS21

## Precision Feedback Controllers

### Fixed and PTAT references

**REV5****INTRODUCTION****DESCRIPTION**

IN-PLUG<sup>®</sup> 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 54mV 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.

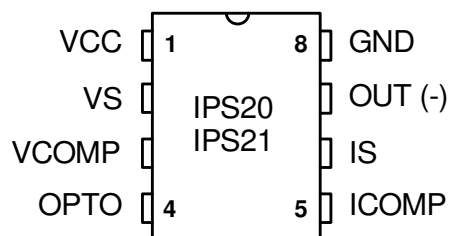
These flyback controllers work best in complement with the IN-PLUG<sup>®</sup> family of IPS1x flyback controllers, IPS10x PFC controllers and IPS20x Push-Pull controllers.

**FEATURES**

- Dual precision regulators for SMPS voltage and current control
- Output currents up to 50A
- Output voltage down to 1.2V
- 54mV or 100mV current sensing voltage
- 1.19V voltage reference
- Operates with grounded optocoupler
- 4V shunt regulator for VCC supply

**APPLICATIONS**

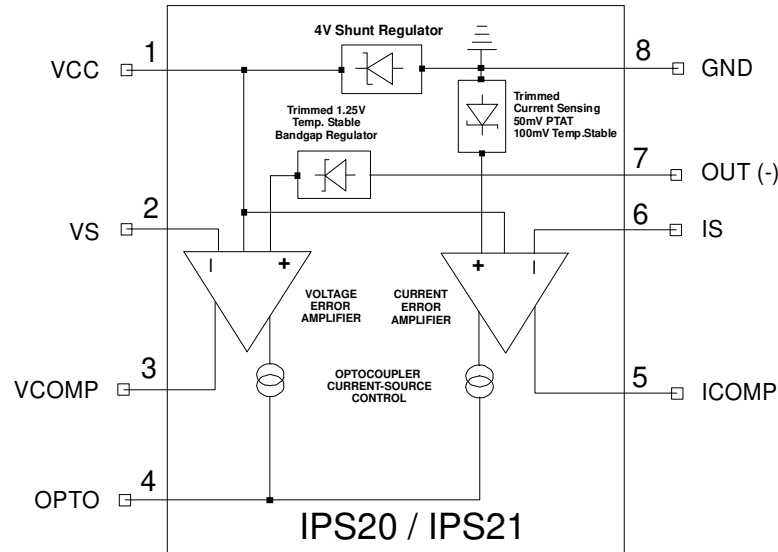
- Fast chargers for power tools and other applications
- Battery eliminators
- Industrial and bench-type power supplies
- Distributed power systems

**PIN CONFIGURATION: DIP-8 / SOIC-8****ORDERING INFORMATION**

For part number, packaging, and ordering information, please refer to the second-to-last page of this datasheet.

## Power Management IPS20 and IPS21

### FUNCTIONAL BLOCK DIAGRAM



### PIN DESCRIPTION

PIN	Description
<b>1- VCC</b>	IC positive supply pin. The chip behaves like a 4 volt zener diode referenced to GND
<b>2- VS</b>	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.
<b>3- VCOMP</b>	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 (1K $\Omega$ nominal).
<b>4- OPTO</b>	Optocoupler driver pin. This pin drives an external optocoupler connected to GND. A current-mode drive is used for maximum noise rejection.
<b>5- ICOMP</b>	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 (1K $\Omega$ nominal).
<b>6- IS</b>	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.
<b>7- OUT (-)</b>	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.
<b>8- GND</b>	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

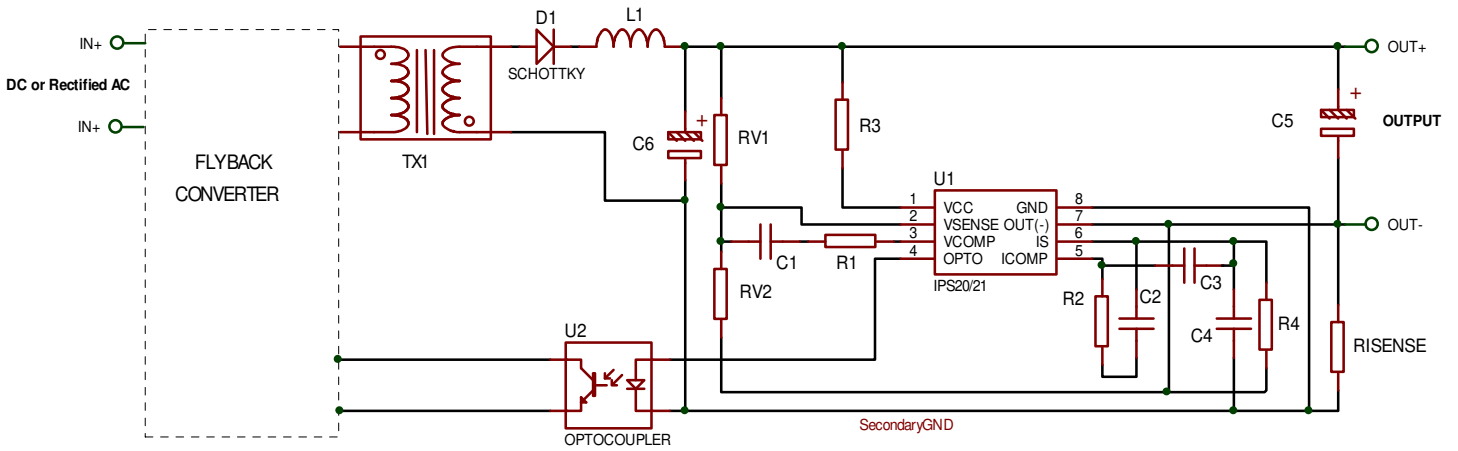


Fig. 1

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.

<p><b>Determination of <math>V_{out}</math> (Output Voltage):</b></p> $V_{out} = VSENSE \times (RV1+RV2) / RV2$ <p>(Nominal VSENSE = 1.19V)</p>	<p><b>Determination of <math>I_{limit}</math> (Current Limit):</b></p> $I_{limit} = IS \text{ threshold} / RISENSE$ <p>Nominal IS threshold :</p> <p>IPS20= 54mV</p> <p>IPS21= 100mV</p>
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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  $\mu$ 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.

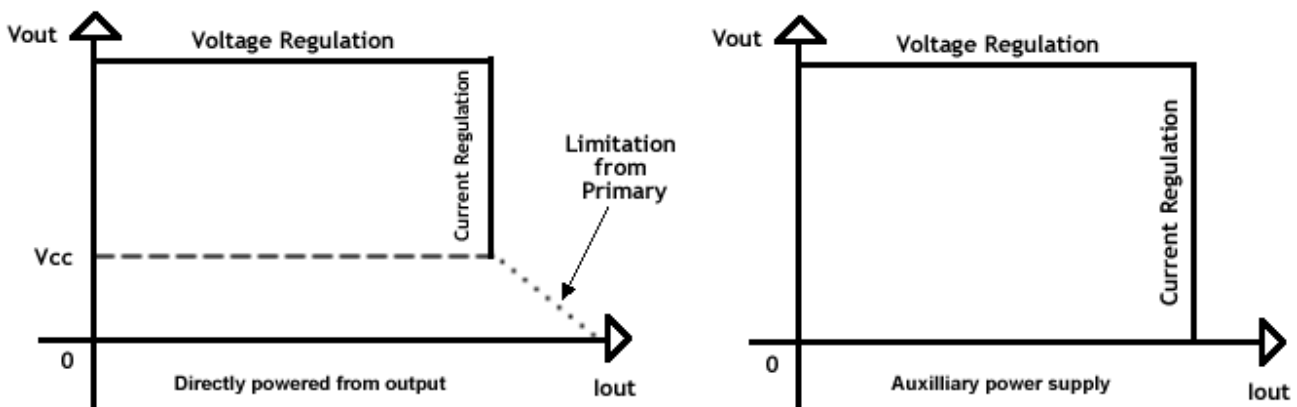


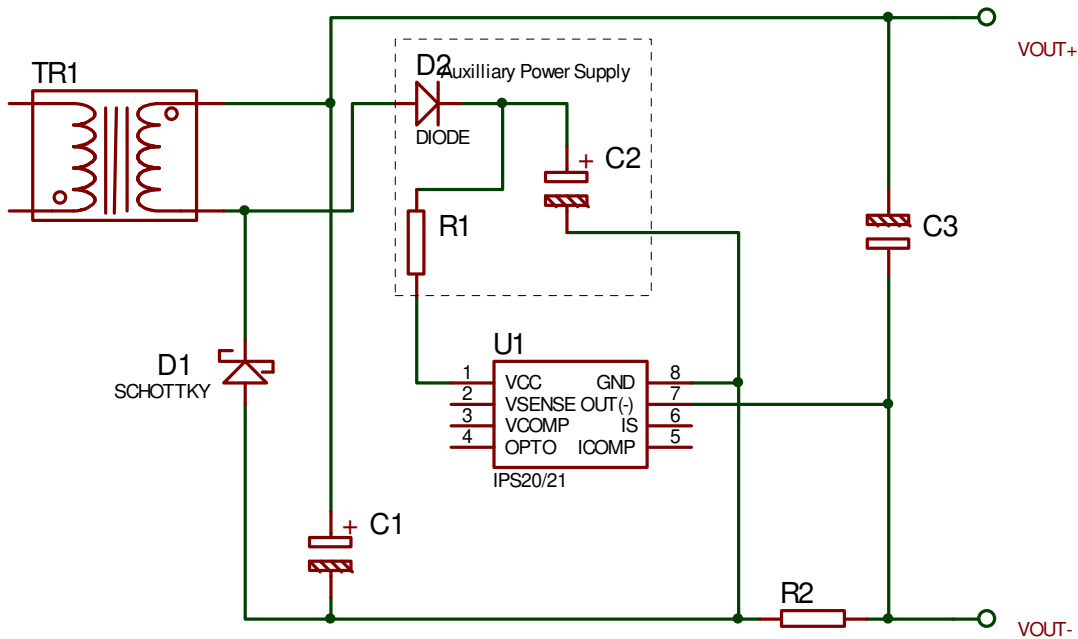
FIG.2 OUTPUT VOLTAGE VERSUS OUTPUT CURRENT

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.

## Power Management IPS20 and IPS21

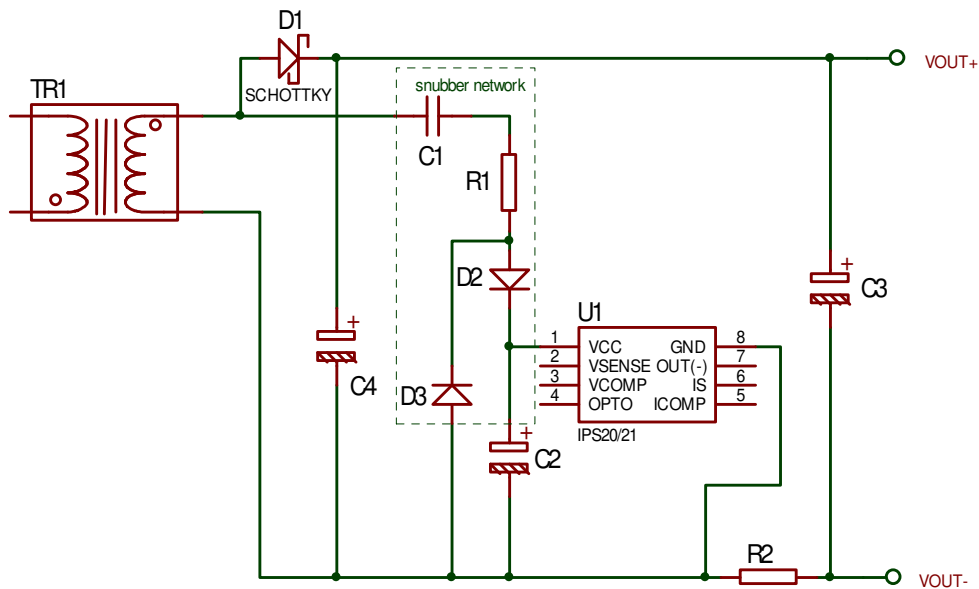
### AUXILLIARY POWER SUPPLY

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.	
<b>Supply, Bias</b>					
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	$\Omega$
Shunt regulator max peak repetitive current		-	100	-	mA
Min $I_{CC}$ to ensure operation (internal current)		-	-	600	$\mu$ A
<b>Voltage Regulation</b>					
VSENSE threshold (note1)	$I_{OPTO} = 500 \mu$ A $Z_{in} = 10K\Omega$	1.17	1.19	1.21	V
VSENSE threshold variation with temperature	$I_{OPTO} = 500 \mu$ A, -40°C to +85°C (see figure 2)	-	+/- 3	+/- 6	mV
Output impedance of VCOMP		-	1	-	K $\Omega$
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		-		1.0	$\mu$ A
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
<b>Current Limiting</b>					
ISENSE threshold (IPS20)	$I_{CC} = 1$ mA (see figure 3)	52	54	56	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	-	$\mu$ V/°C
Output impedance of ICOMP		-	1	-	K $\Omega$
Voltage gain to ICOMP	(see figure 8)	-	138	-	dB

## Power Management IPS20 and IPS21

Unity gain bandwidth to ICOMP	(see figure 8)	-	2	-	MHz
Phase margin in unity gain		-	54	-	Degrees
I <sub>SENSE</sub> Input current		-		-1.0	uA
Transconductance from I <sub>SENSE</sub> to OPTO	(see figure 6a & 6b) IPS20: 6a, IPS21: 6b	-	60	-	mA/mV
Max OPTO output sourcing current without ext. resistor	@ V <sub>CC</sub> = 1.30V (see figure 5)	1.2	-	-	mA
Max OPTO output sourcing current with ext. resistor	@ V <sub>CC</sub> = 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.

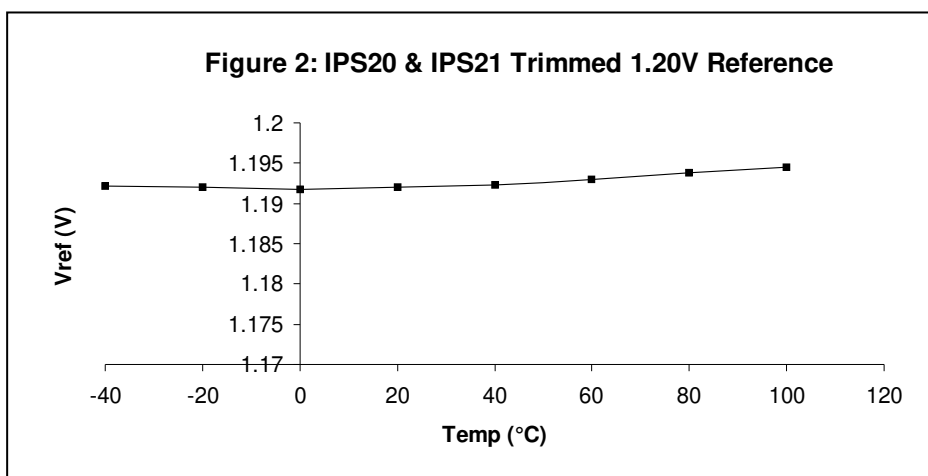
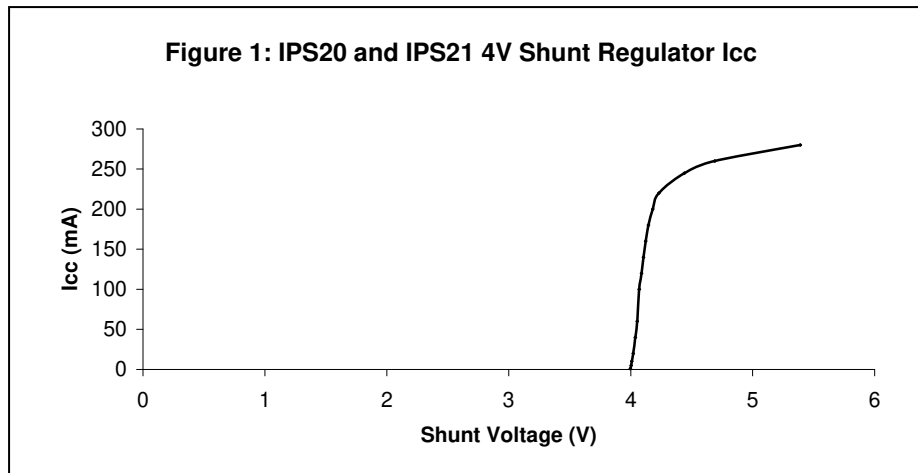




Figure 3: IPS20 Ref. with copper temperature drift compensation

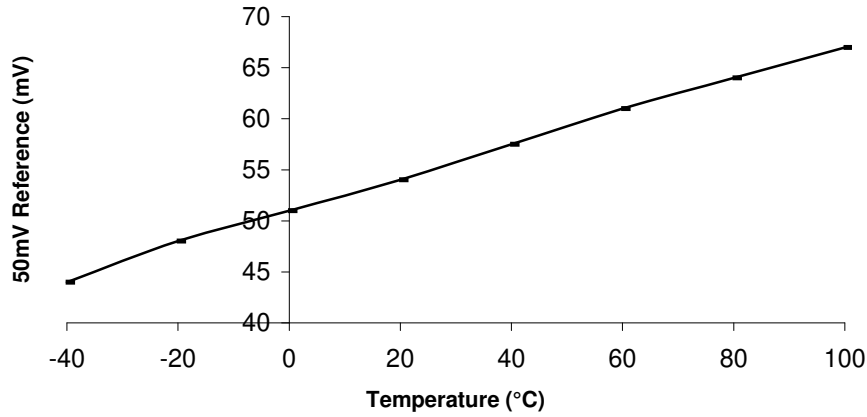


Figure 4: IPS21 100mV Reference

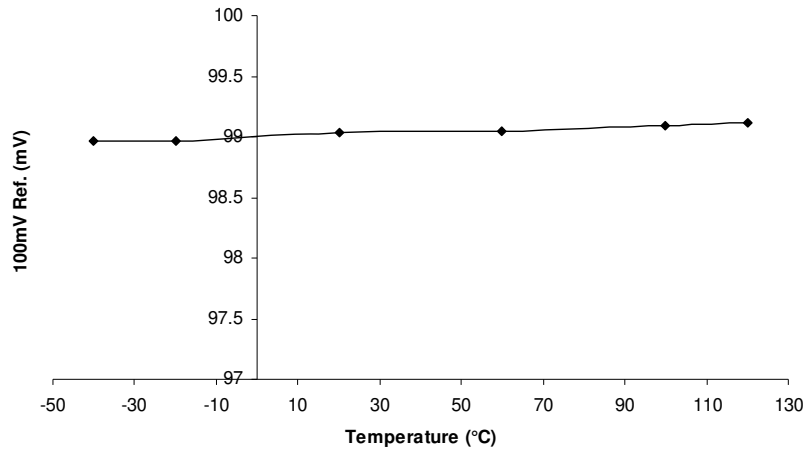
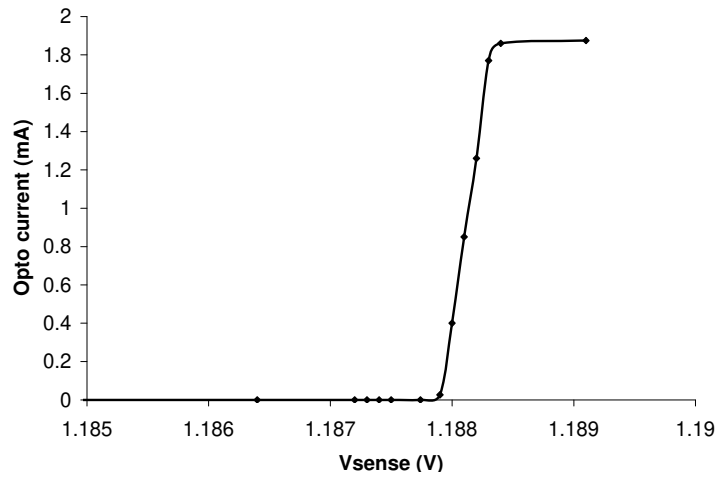
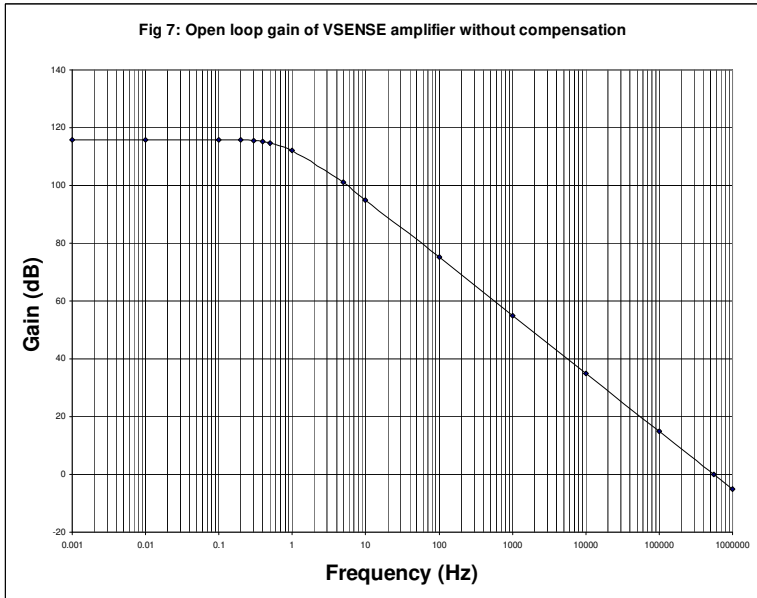
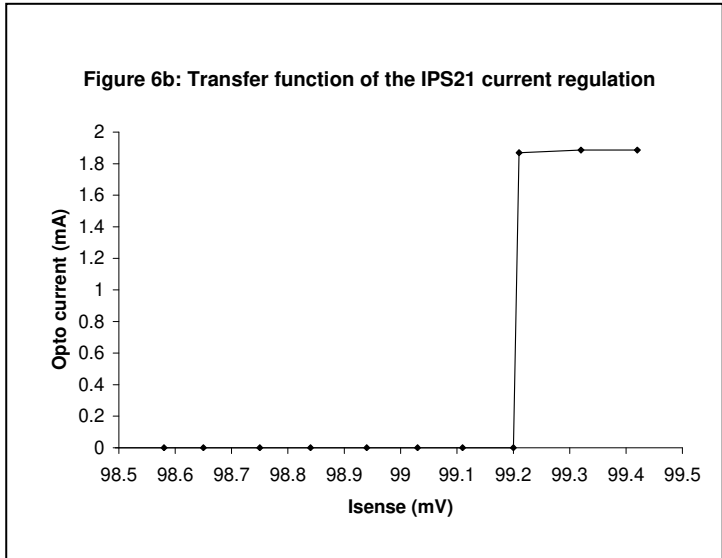
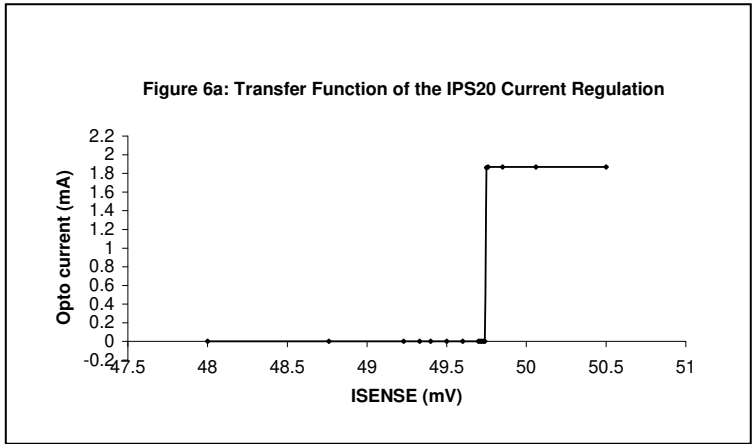
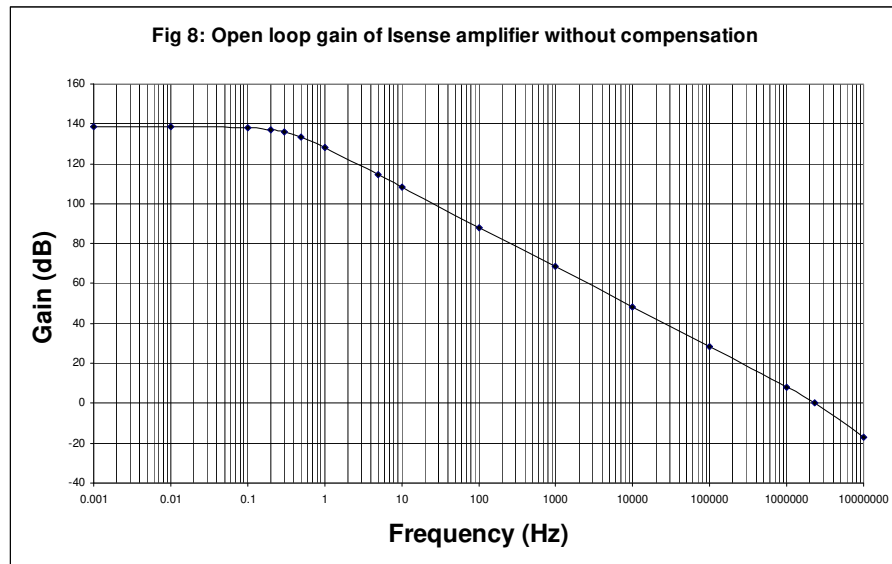


Figure 5: Transfer function of the voltage regulation







### 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 (Pin 1 - 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).

## EVALUATION BOARD

There is an evaluation board (AAEV2021) available for the IPS20 and IPS21 feedback controllers. Contact AAI Marketing for more details. There are also benchmark/reference designs available that include AAI Flyback Controllers, and Application Notes.

## PACKAGE DIMENSIONS AND MARKING

The IPS20 and IPS21 are available in plastic 8-pin DIP and plastic 8-pin SOIC packages. Refer to the latest version of specification AAPS001 (ASIC Advantage’s “Package Numbering, Marking, and Outline Standard”, available at [www.asicadvantage.com](http://www.asicadvantage.com)) for specific information concerning the package dimensions and package marking.

Part Number/Tube	Part Number/Tape&Reel	Package	Temperature Range	
			Min	Max
IPS20C-D-G-LF IPS21C-D-G-LF	NA	8-Pin PDIP	0°C	+70°C Commercial
IPS20I-D-G-LF IPS21I-D-G-LF	NA	8-Pin PDIP	-40°C	+85°C Industrial
IPS20C-SO-G-LF IPS21C-SO-G-LF	IPS20C-SO-G-LF-TR IPS21C-SO-G-LF-TR	8-Pin SOIC	0°C	+70°C Commercial
IPS20I-SO-G-LF IPC21I-SO-G-LF	IPS20I-SO-G-LF-TR IPC21I-SO-G-LF-TR	8-Pin SOIC	-40°C	+85°C Industrial

## **Power Management IPS20 and IPS21**

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