Designing with the DRV421: System Parameter Calculator

Precision Analog – Energy Solutions Products

ABSTRACT

The DRV421 is a signal conditioning integrated circuit for use in closed-loop magnetic current sensor modules. The DRV421 is designed with an internal fluxgate sensor to provide superior performance and simplify system design. The DRV421 contains all the necessary excitation and signal conditioning circuitry to drive the current-sensing feedback loop. This application note discusses how to use a Microsoft® Excel® spreadsheet to facilitate the design of a closed loop current sensor using the DRV421. Project collateral discussed in this application report can be downloaded from the following URL: http://www.ti.com/lit/zip/SLOA225.

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1 Introduction

An easy-to-use Excel spreadsheet was developed to help facilitate the design of a closed-loop current sensor featuring the DRV421. The spreadsheet allows the designer to enter various system-level parameters such as the desired measurement range, the supply voltage, the reference, among others. The spreadsheet will calculate the system gain, the compensation current and the necessary shunt resistor size.

Output graphs showing the open loop gain and phase response, the gain versus frequency and the primary-to-secondary gain versus frequency are also provided.

2 User Inputs

The Summary Tab of the spreadsheet allows the user to enter their desired system and magnetic core parameters. Figure 1 provides an example:

Current Sensor Parameter Input

System Parameters	Value	Unit	Notes:
Desired Current Measurement Range:	50.00	A	Largest peak current that is measurable by current sensor
Supply Voltage:	5.00	V	
Reference Voltage Setting:	0		RSEL[1,0] pin setting: 0,1,2,3
Reference Output Voltage Selected:	2.50	V	
Shunt Sense Amplifier Reference Voltage:	2.50	V	Enter 'Reference Output Voltage' or voltage applied to REFIN pin
Chosen Shunt Resistor:	20.00	Ohm	
Maximum Operation Temperature:	85	°C	Will be used for drift calculations
Magnetic Core Parameters	**Value**	**Unit**	
Compensation Coil Inductance:	5.00E-01	H	Minimum 100mH, recommended 300mH - 2H
Compensation Coil Resistance:	10.00	Ohm	Keep voltage compliance in consideration
Number of Compensation Coil Windings:	1000	Turns	
Magnetic Gain of Magnetic Core:	5.00E-04	T/A	A typical value is 600 - 700uT/A
Recommended Gain Setting (GSEL[1:0]):	3		See datasheet for gain setting recommendation
Chosen Gain Setting (GSEL[1:0]):	2		GSEL 0,1,2,3

Figure 1. User System and Core Parameter Inputs

The desired system parameters are entered along with the properties of the magnetic core. In this section, the *Reference Output Voltage* is based on the value entered in the reference setting cell. The number entered in the Reference setting cell is based on the binary value of the REFSEL[1:0] pins. See the DRV421 datasheet (SBOS704) for additional details.

In the magnetic core parameters section, the recommended gain setting for GSEL[1:0] is provided based on the parameters entered for the compensation coil inductance, resistance, number of winding, and the magnetic gain of the core material. The spreadsheet allows the user to override the recommended gain and enter their own value (0−3) based on the binary value of the GSEL[1:0] pins.

3 Calculated Outputs

Based on the user values entered in section 2 and as shown in Figure 2, the spreadsheet will calculate the system gain, the compensation current under normal and overload conditions, and calculates the maximum allowable shunt resistor size.

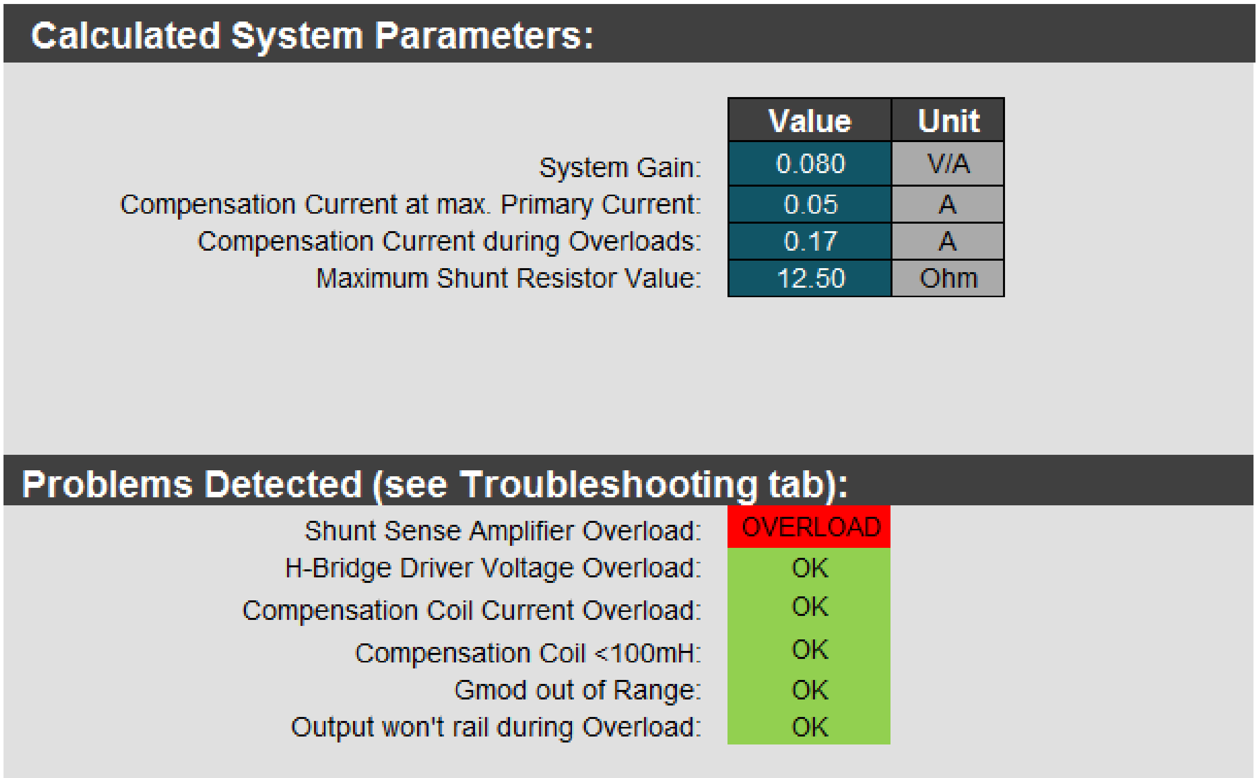


Figure 2. Calculated Outputs

As can be seen in Figure 2, the spreadsheet also detects errors and provides the user with overload and warning indicators. In this case, the shunt resistor chosen in section 1 was 20 Ω. Based on the other system parameters entered by the user, the shunt resistor maximum value was calculated to be 12.50 Ω maximum. Another cause of the overload condition may be related to the entered number of compensation coil windings as discussed in the next section.

4 Troubleshooting

This section provides the user with feedback based on the entered parameters for the system and the magnetic core properties.

Shunt Sense Amplifier Overload:

Description: At the entered desired current range, the input voltage across the shunt is too high, causing the differential amplifier to rail.

Solution: Reduce the shunt resistor size or increase the number of compensation coil windings.

H-Bridge Driver Overload:

Description: For the desired current measurement range, the DRV421 driver stage is not able to deliver enough compensation current, since the total secondary resistance (shunt resistance + comp coil resistance) is too high. The driver will therefore rail.

Solution: Reduce the compensation coil size, and/or reduce the shunt resistor size.

Compensation Coil Current Overload:

Description: For the desired current measurement range, the DRV421 driver stage is not able to deliver enough compensation current, as it exceeds its drive capability at the given supply voltage.

Solution: Increase the number of compensation coil windings and/or increase the supply voltage.

Compensation coil < 100 mH

Description: A compensation coil inductance < 100 mH was entered. For loop stability and robust operation during overload currents, DRV421 must be used with a compensation coil of 100 mH minimum. A larger inductance is recommended to improve robustness.

Solution: Increase the compensation coil inductance.

G_{MOD} out of range

Description: The stability gain factor G_{MOD} is out of range. No valid GSEL settings can be found that guarantee stable operation of the loop. See the DRV421 datasheet (SBOS704) and application note *Designing with the DRV421: Control Loop Stability* (SLOA244) for more details.

Solution: Change the compensation coil inductance, number of compensation windings to ensure stable operation.

Output will not rail during overload

Description: The system is dimensioned such that during an overload current (that is, a current greater than the designed measurement range), the analog output voltage will not rail. While this is not a problem for the current measurement module on itself, some end customers may judge from the output that the sensor is working properly, as the output voltage is not in the rail. However, the output is invalid during overloads.

Solutions:

1) Increase the value of the shunt resistor to ensure that an overload current causes the differential amplifier to rail.

2) Ensure that in the end application, the error pin is monitored such that an overload current is correctly detected. When the error pin is pulled low, the analog output is invalid.

5 Error Components

The error contributions based on user inputs include the sensor offset, sensor offset over temperature; the shunt sense amplifier offset, and gain components as shown in Figure 3.

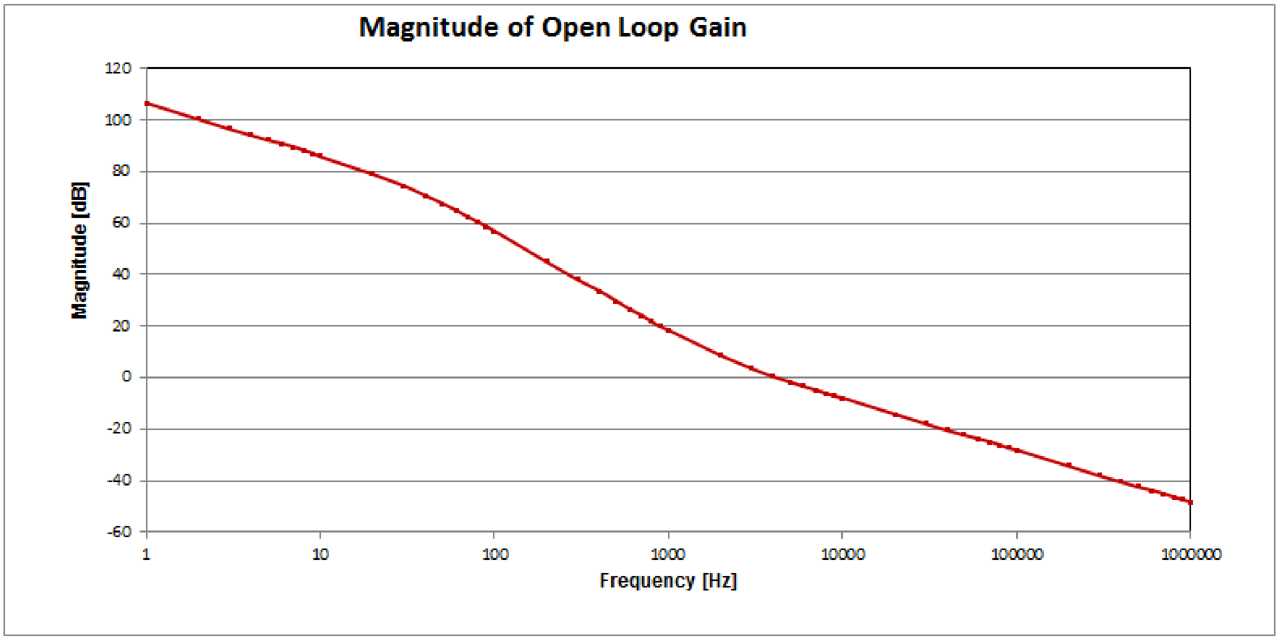
Error Contributors Referred to Primary Current:

Fluxgate Offset Error Contribution:	***Typical***	***Max***	***Unit***
Sensor Offset (no demagnetization):	2.0	16.0	mA
Sensor Offset over Temperature:	1.2	2.3	mA
Noise:	0.13		mArms
Shunt Sense Amp. Offset Error Contribution:			
Shunt Sense Amplifier Offset:	0.10	1.04	mA
Shunt Sense Amplifier Offset over Temperature:	0.24	1.21	mA
Shunt Sense Amplifier Input Impedance:	0.00		mA
Shunt Sense Amp. Gain Error Contribution:			
Shunt Sense Amplifier Gain Error:	0.020	0.300	%
Shunt Sense Amp. Gain Error over Temperature:	0.006	0.029	%
Shunt Sense Amp. Common-Mode-Rejection-Ratio (CMRR):	0.001	0.005	%

Figure 3. Error Components

6 Output Plots

Based on the user's desired system parameters and magnetic core parameters entered into the spreadsheet, plots for the open-loop gain and phase are provided as well as plots showing the closed-loop model frequency response. Example plots are shown in Figure 4 and Figure 5.



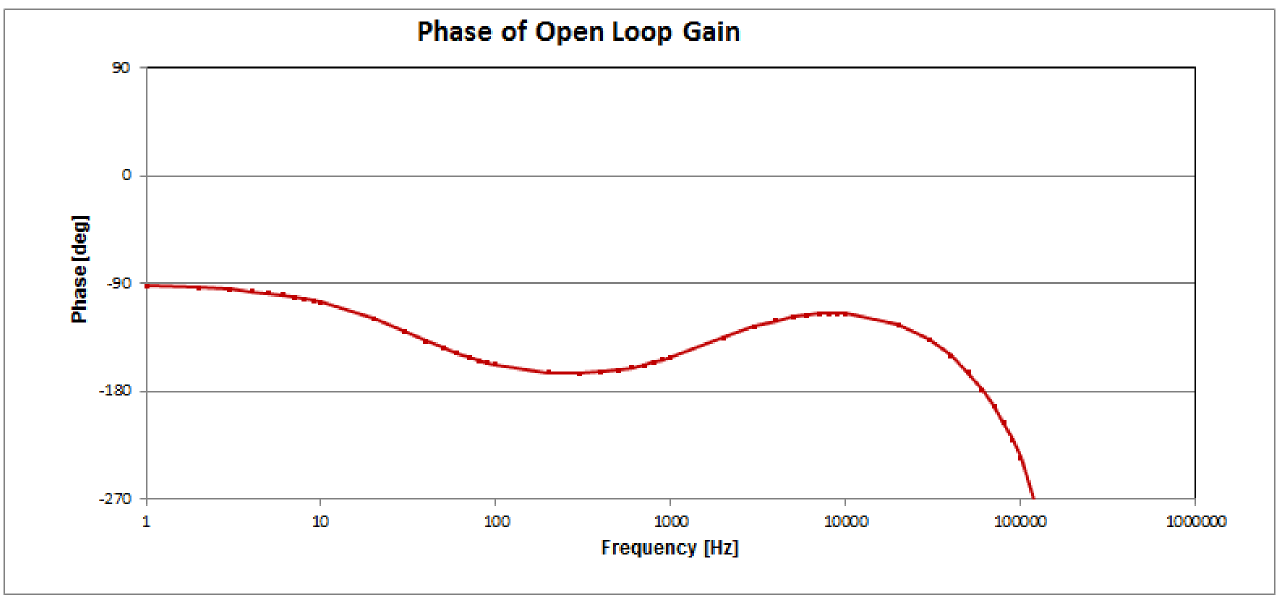


Figure 4. Open Loop Gain and Phase Response

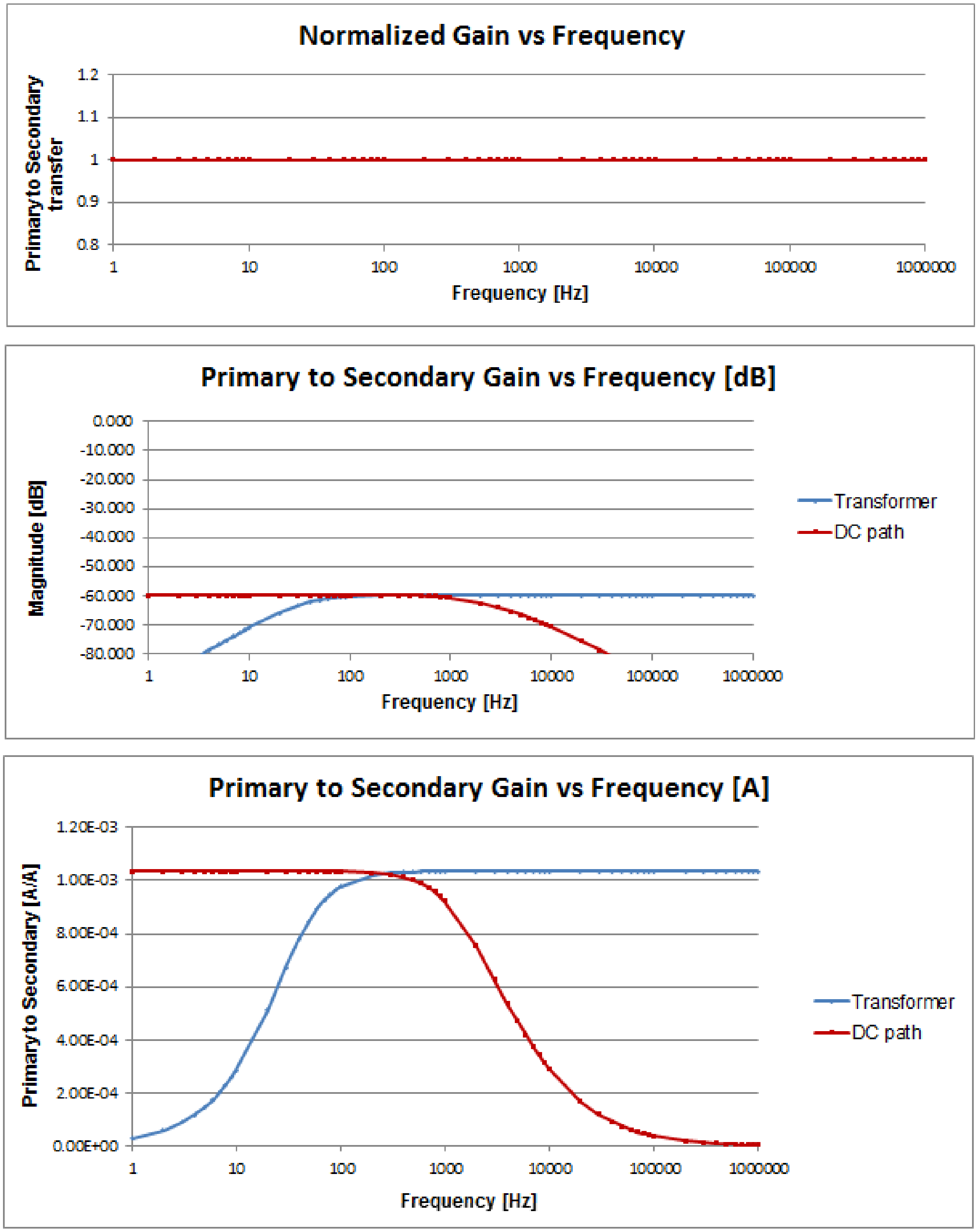


Figure 5. Closed Loop Gain vs. Frequency Response

7 Summary

This easy-to-use Excel spreadsheet will help the designer of a closed-loop current sensor using the DRV421 with some of the basic equations necessary to facilitate a stable system design. The spreadsheet allows the designer to enter and modify various system and core-level parameters to quickly see the impact on the overall system solution.