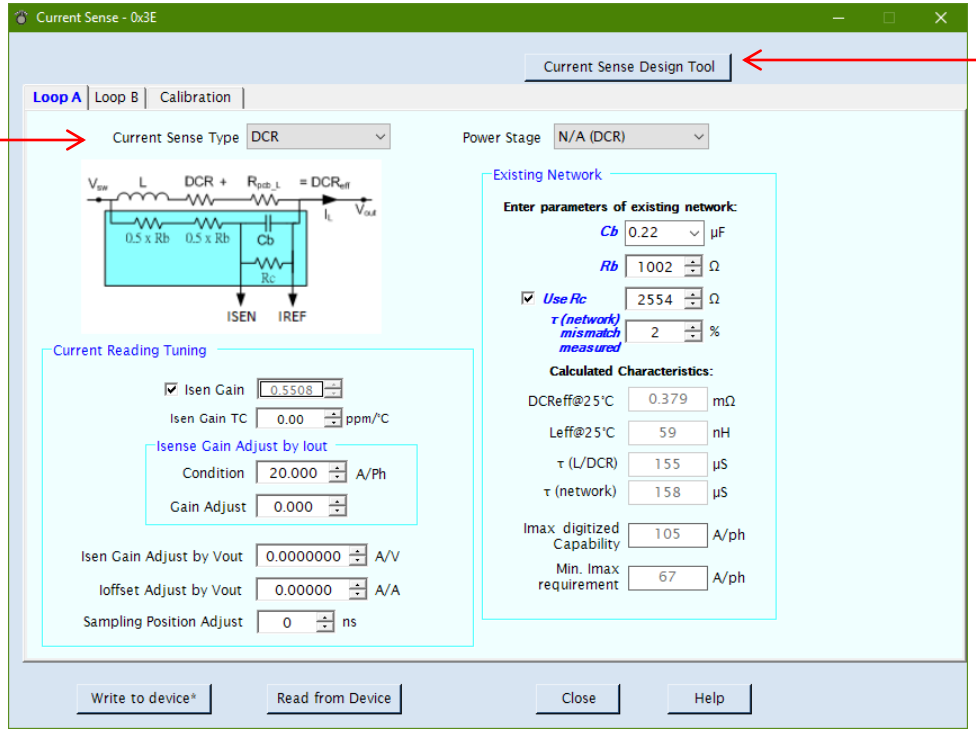
Current sense...

Current Sense Type

- For XDPE1x286 and XDPE12550 part, selection can be *DCR* sense (as shown), *DCR Shunt* or *Non-DCR* (i.e. power stage with internal current sense)
- For other parts, current sense type will automatically change to *Non-DCR*
- Graphical figure will change to match selection made



Current Sense Design Tool

- Dialog that helps calculate the settings and any resistors needed

Current sense... DCRsense

Isen Gain
- Gain factor for the measured voltage across Cb that represent the current through the inductor
- Tune this value such that the current reading gain is accurate from 0A to 2/3 of TDC with **Isen Gain TC** set at 3906.25ppm/°C when temp change in inductor is small
- To get a starting value set the gain=0.15mV/DCR

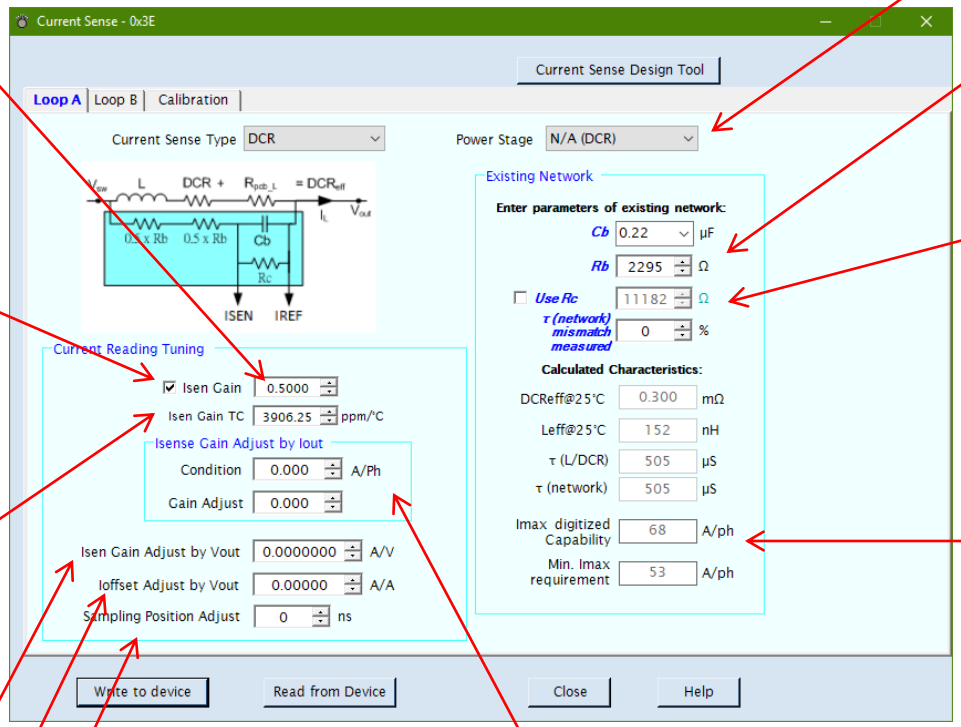
Isen Gain checkbox
- Checked: override calibrated gain settings from the *Calibration* tab
- Unchecked: gain will use values from the *Calibration* tab

Isen Gain TC
- Temperature Coefficient for gain
- Typically between 2000 ~ 4000 ppm/°C
- Use the ideal copper TC=3906.25 first and then based on temperature compensation result of inductor DCR to trim this value
- This value could be different by layout.

Isen Gain Adjust by Vout
- Linear current sense gain compensation based on Vout

Ioffset Adjust by Vout
- Offset f the current sense based on Vout

Sampling Position Adjust
- Adjustment of reported phase current in the ***Telemetry*** window
- See next page for explanation



Power Stage
- When **Current sense Type** is *DCR*, selections are *DCR* and *Sense Resistor*

Cb and **Rb**
- Enter the real values used on the PCB for capacitor and resistor
- Cb typical 0.22uF

T (Network) mismatch measured
- This is the mismatch in the two time constants Rb*Cb and L/DCR for the real components
- Typical put a value 1-2%
- Explanation follows on the next pages

Imax Digitized and **Min. Imax requirement.**
- Check that the calculated **Imax Digitized** capability is equal or higher than **Min Imax Requirement**
- If not try to add more Rc to get a lower voltage on the ISEN-Iref signals. This to not exceed the 30mV input range for the current sense input for DCR.

Isen Gain Adjust by Iout
- Optional gain adjustment to the current sense based on Iout
- Compensate for a non-linear behavior in current reporting for small currents
- For load currents greater than the specified A/ph Condition, the specified **Gain Adjust** value will be applied
- Recommended setting for **Condition** is 16~20A/ph

$$Isen\ Gain\ @\ I_x\ per\ phase = Isen\ Gain * (I_x - I_{condition}) * (1 + GainAdjust)$$

Current sense... Sense resistor

Isen Gain
- Gain factor for the measured voltage across Cb that represent the current through the inductor
- Tune this value such that the current reading gain is accurate from 0A to 2/3 of TDC with **Isen Gain TC** set at 3906.25ppm/°C when temp change in inductor is small
- To get a starting value set the gain=0.15mV/DCR

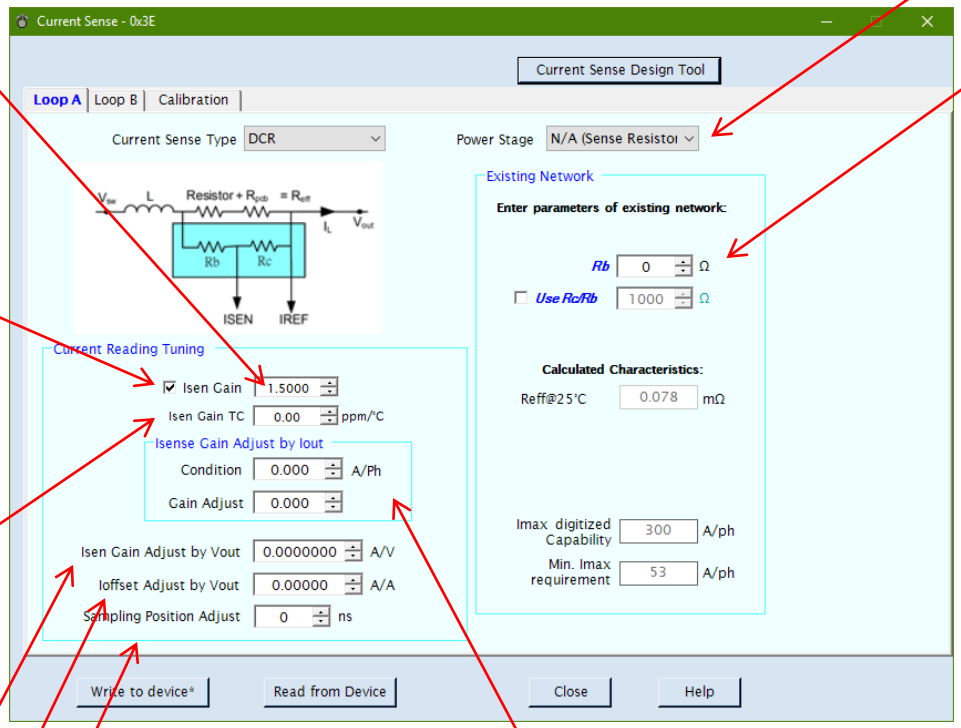
Isen Gain checkbox
- Checked: override calibrated gain settings from the *Calibration* tab
- Unchecked: gain will use values from the *Calibration* tab

Isen Gain TC
- Temperature Coefficient for gain
- Typically between 2000 ~ 4000 ppm/°C
- Use the ideal copper TC=3906.25 first and then based on temperature compensation result of inductor DCR to trim this value
- This value could be different by layout.

Isen Gain Adjust by Vout
- Linear current sense gain compensation based on Vout

Ioffset Adjust by Vout
- Offset f the current sense based on Vout

Sampling Position Adjust
- Adjustment of reported phase current in the ***Telemetry*** window
- See next page for explanation



Power Stage
- When **Current sense Type** is *DCR*, selections are *DCR* and *Sense Resistor*

With a sense resistor instead of DCR sense, the resistor divider is often 0ohm.

Typically temperature dependance TC is much less than for DCR. See resistor vendors datasheet for value.

Isen Gain Adjust by Iout
- Optional gain adjustment to the current sense based on Iout
- Compensate for a non-linear behavior in current reporting for small currents
- For load currents greater than the specified A/ph Condition, the specified **Gain Adjust** value will be applied
- Recommended setting for **Condition** is 16~20A/ph

$$Isen\ Gain\ @\ I_x\ per\ phase = Isen\ Gain * (I_x - I_{condition}) * (1 + GainAdjust)$$

Current sense... Non-DCR

Isen Gain
- Gain to use for all phases for the signal from the power stage
- To get a starting value, set the gain=0.35 when using a power stage like TDA21460

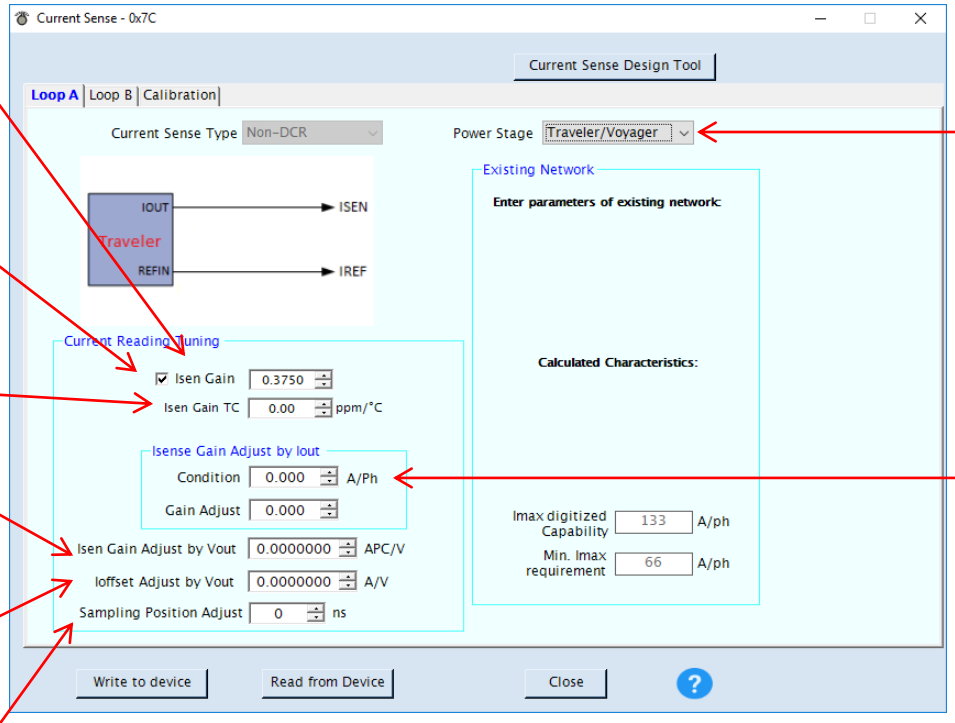
Isen Gain checkbox
- Checked: override calibrated gain settings from the *Calibration* tab
- Unchecked: gain will use values from the *Calibration* tab

Isen Gain TC
- Temperature Coefficient for gain
- Typically set to 0

Isen Gain Adjust by Vout
- Linear current sense gain compensation based on Vout

Ioffset Adjust by Vout
- Offset f the current sense based on Vout

Sampling Position Adjust
- Adjustment of reported phase current in the ***Telemetry*** window
- See next page for explanation



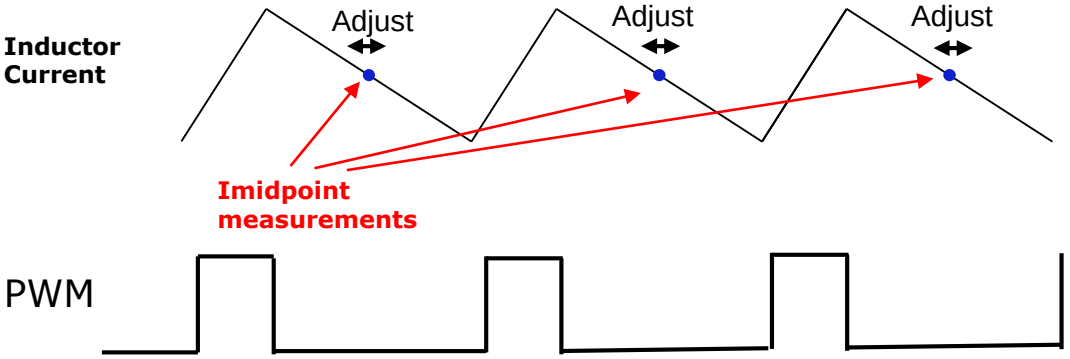
Power Stage
- When **Current sense Type** is *Non-DCR,* select device name family depending on the power stage being used
- *Traveler/Voyager*
- *Big Rock*
- *Sapphie/Denali*

Isen Gain Adjust by Iout
- Optional gain adjustment to the current sense based on Iout
- Compensate for a non-linear behavior in current reporting for small currents
- For load currents greater than the specified A/ph Condition, the specified **Gain Adjust** value will be applied
- Recommended setting for **Condition** is 16~20A/ph

$$Isen\ Gain\ @\ I_x\ per\ phase = Isen\ Gain * (I_x - I_{condition}) * (1 + GainAdjust)$$

Current Sense…

- Sampling Position Adjust. Will influence the Phase current in Telemetry window
  - Current is measured at every Imidpoint of the falling edge of inductor current and the controller use this for current balance function and report the per phase current in telemetry window
  - Sometimes the inductor current curve is not perfect. Delays in powerstage and distortion shift the curve and the reported phase current will not be the actual average phase current.
  - This setting allow for some adjustment to get closer to the mid point of inductor current that is then reported in Telemetry window as phase current.
  - Current balance is not influenced as it still compare all phases at same point in time.



With Adjust as negative the sampling occur earlier equals higher reported current
Positive number delays the sampling and reports a lower phase current

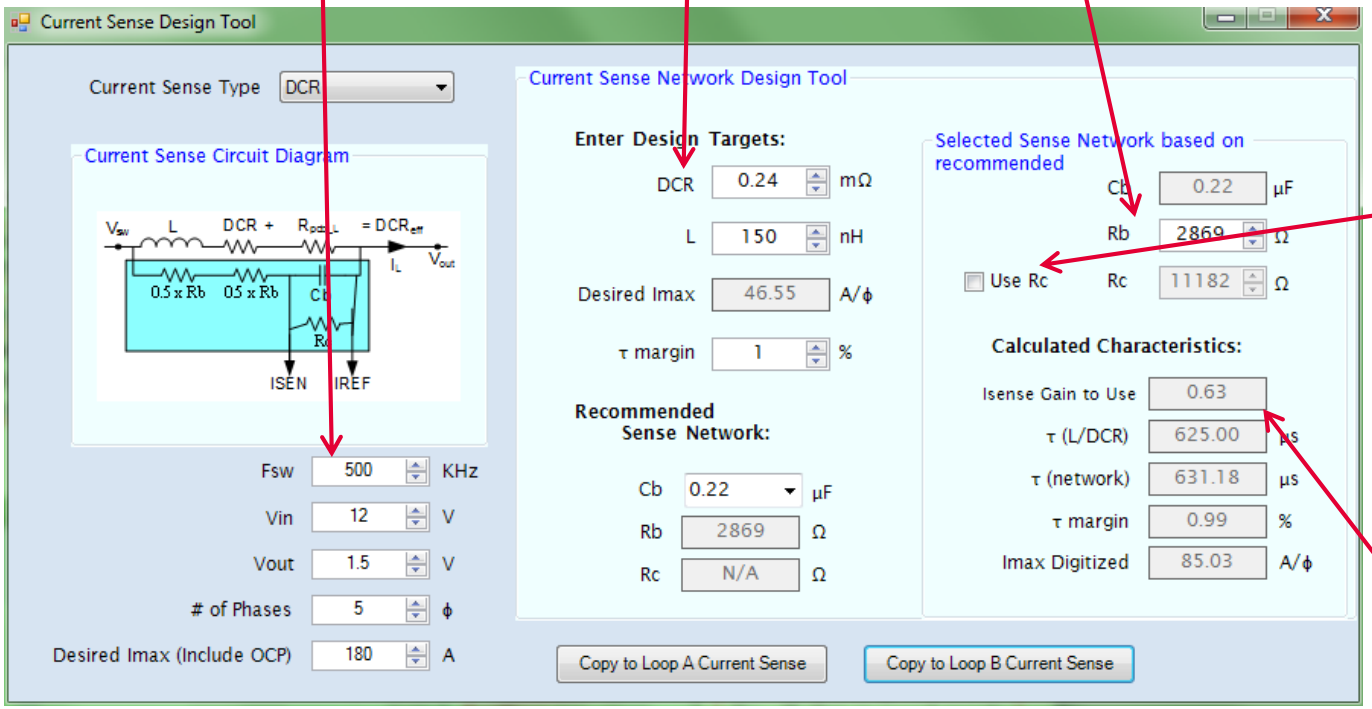
Current sense... Current sense design tool

A tool to help calculate current sense parameters. Use knowledge from the 3 following theory slides to find suitable numbers to enter.

First enter some basic numbers for the design

2nd step. Enter Data for inductor used
And the Cb capacitor 0.22uF recommended.
T margin typical 2%

3rd step. Enter Data for Rb resistor



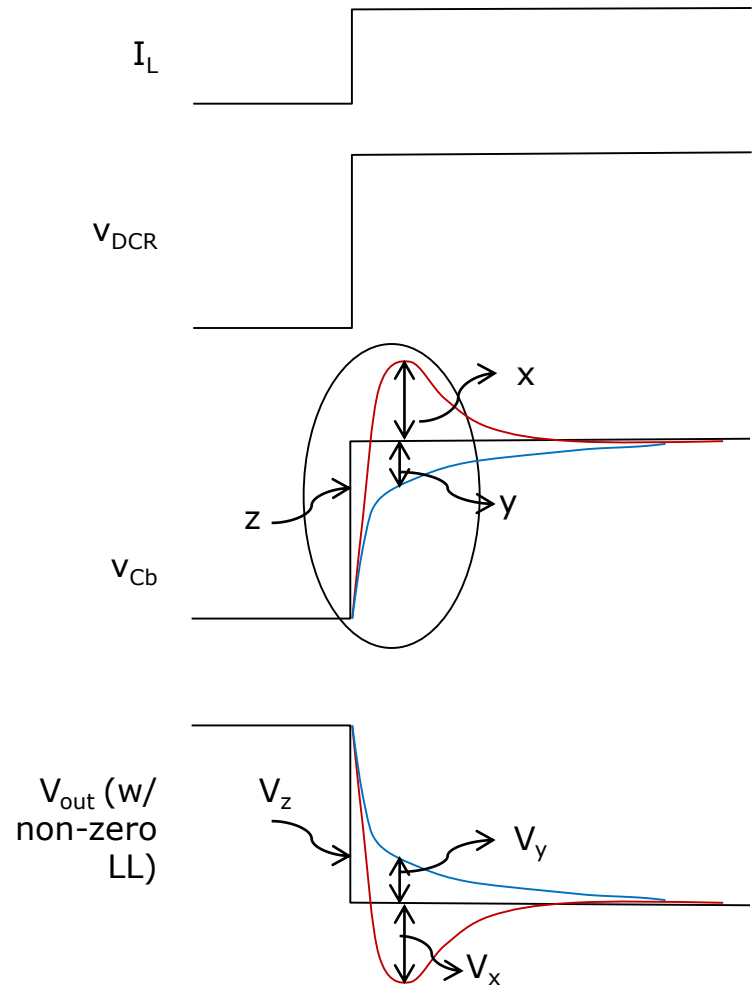
Use Rc. If there is a high DCR value the sense voltage may be needed to be divided down by using resistor Rc. If this is used mark the box and enter a number in the **Rc** field

Isense gain. Calculated value that can be used as Isense gain in the current sense window.

It is to be used as starting point as final gain is determined by testing.

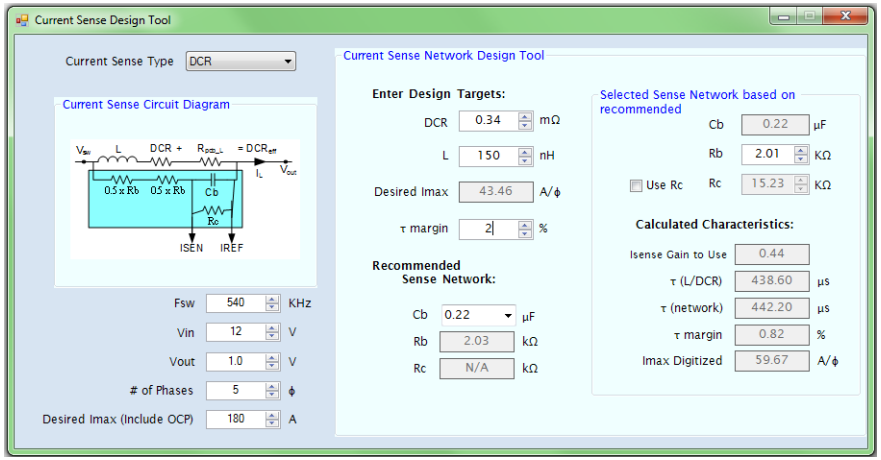
Current sense... dynamic response: Rb*Cb time constant

$$v_{Cbx} = v_{DCRx} * \frac{L/DCR}{R_b * C_b}, \quad s \to \infty$$



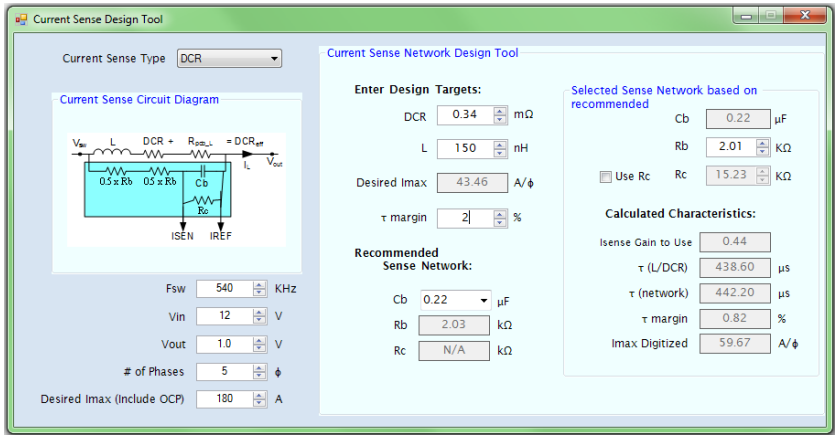
- Impact of how Rb*Cb compared to L/DCReff:
  - If R_b*C_b = L/DCReff, v_{Cb} will be the same v_{DCR} at any frequency
  - If R_b*C_b < L/DCReff, v_{Cb} will underdamp v_{DCR} which leads to overshoot/undershoot during transient when LL is non-zero. To adjust time constant:
    - $(R_b*C_b)_{new} = (R_b*C_b)_{orig}*(1+x/z)$
  - If R_b*C_b > L/DCR, v_{Cb} will overdamp v_{DCR}. To adjust time constant:
    - $(R_b*C_b)_{new} = (R_b*C_b)_{orig}*(1-y/z)$

Current sense... Adjust DCR sense network time constant – method 1: using transient waveforms with non-zero LL slope (1 of 2)



- The DC current sense gain must be tuned before adjusting time constant → actual DCR on board $DCR_{eff@25degC} = DCR_L + DCR_{trace}$ can be calculated
- Step 1: enter C_b and R_b values used on the board
- Step 2: set up transient load from 5% TDC to 55% TDC and measure z and x or y in previous page
- Step 3: if V_{Cb} overshoots V_{DCR}, enter x/z to "τ mismatch measured"; otherwise, enter –y/z to "τ mismatch measured" → actual L can be calculated

Current sense... Adjust DCR sense network time constant – method 1: using transient waveforms with non-zero LL slope (2 of 2)



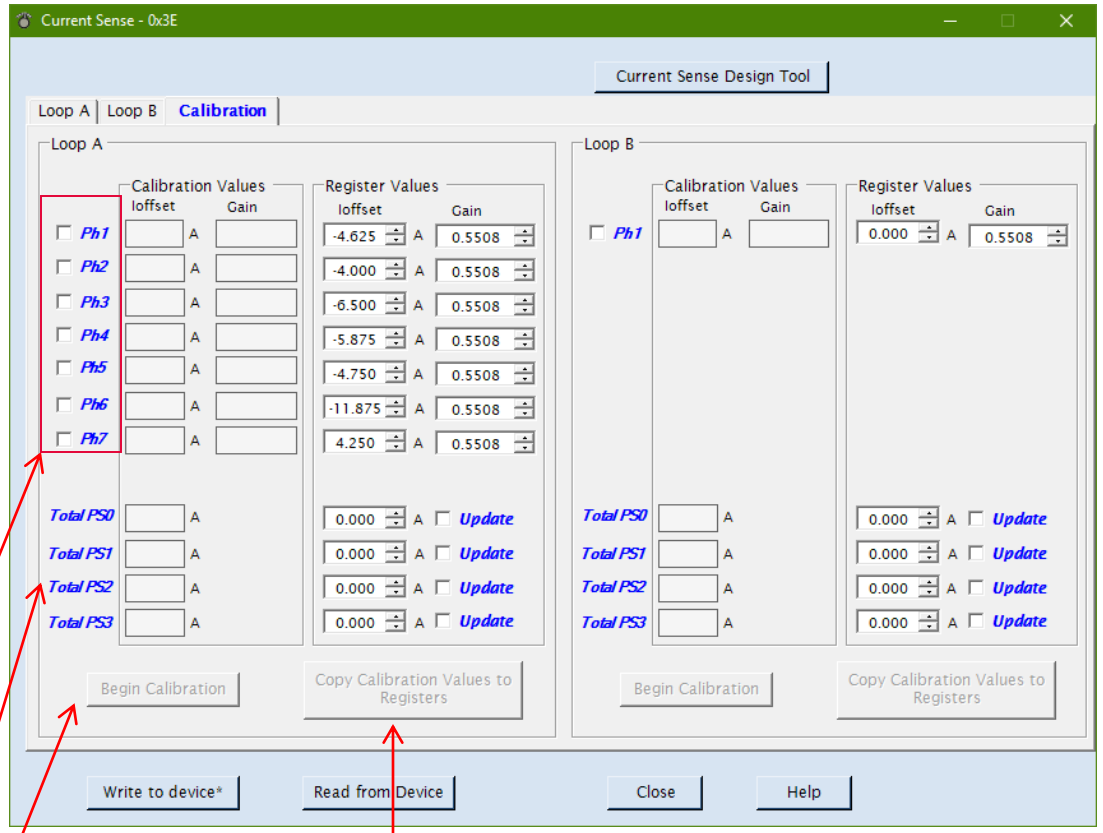
- Step 5: Select the desired C_b value and then R_b will be calculated automatically
  - Tip: recommend to keep the same C_b value and only adjust R_b value to minimize modifications on board
- Step 7: change the R_b or C_b to the new values on the board and verify DC current reading and time constants matching again
  - Iteration of DC current reading and time constant adjustments might be necessary

Current sense... Calibration

- Partly automated calibration of offset and gain per phase.
- Optimizes the reported current and compensate for variations between phases.
- It is also possible to manually enter values into the **Register Value** section.

Calibration Procedure

1. Check the **Phx** checkbox to select which phase(s) to calibrate.
2. Click **Begin Calibration** button
   - A series of pop up windows will guide the user when to turn on/off the load.
   - Note: max of 30A per phase
   - GUI will measure telemetry values in each phase in sequence with no load and with load and will calculate offset and gain for each selected phase.
   - Calculated calibrated values will be displayed in the *Calibration Values* column.
3. Click on the **Copy Calibration Values to Registers** button to copy the values to the register section.
4. Click the **Write to device** button to write them into memory of the controller.



Phx

- When checked, phase x will calculate the suggested calibration values for Ioffset and Gain.

Total PSx - Ioffset

- Total Ioffset for each PS states.
- During calibration, calibrated values are automatically changed to 0
- Selecting the **Update** checkbox will copy these values to its equivalent Register Values dialog fields when **Copy Calibration** button is selected

Begin Calibration

- When selected, it will start the calibration process.
- Only enabled when at least 1 **Phx** checkbox is selected.

Copy Calibration Values to Registers

- This will copy the calculated *Calibration Values* column to the *Register Values* column.
- **Write to device** button needs to selected to write to the actual registers

Current sense... Calibration

Differences in DCR sense, power stages or layout can make each phase differ slightly in **Gain** and **Ioffset**.

Gain will be locked against changes if the "hook" on Loop A or B tab is marked as then all Gain is forced to the same setting as entered in Loop tab.

Ioffset
- Offset current for each phase.
- Can be entered manually or automated by the calibration function

Gain
- Gain for each phase.
- Can be entered manually or automated by the calibration function.

Total PSx Ioffset
- Adjustment of reported current for different PowerStates.
- As PowerStates may use different number of phase, the reported current may change and can be compensated by adding an offset.