TRIMMING THE OUTPUT VOLTAGE OF DC/DC CONVERTERS

How do you trim the output of a DC/DC converter when the reference of the error OPAM is referenced to -V_{OUT}?

The simplest and least expensive solution is to connect a resistor from the V_{OUT} Adjust pin to the minus (-) reference point or to the plus (+) reference point (positive point where the feedback RF resistor is connected. When a variable voltage source, such as a digital-to-analog converter (D/A) or OPAM, must be used for adjustment, the circuit in Figure 2 can be used. The circuit in Figure 1 is a variable current source that can be used to perform a ±10% adjustment of the converter's output voltage.

The current, I, in Figure 2 is given by:

$$\frac{VA}{R} = I \qquad \text{Eq.1}$$

and the output voltage is given by:

$$V_O\Big|_{RX\to\infty} = 2V_{OUT} = V_{REF}\left(\frac{RF}{R_{IN}}+1\right) - I\left(\frac{RF}{R}\right) \qquad \text{Eq.2}$$

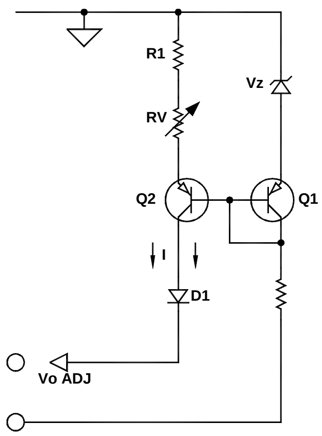

FIGURE 1. Variable current source
I = VZ/(R1+RV)
Q1, Q2 = 2N3906 (or matched pair)
VZ = Low TC zener diode, «V_O

From Eq.2, it can be seen that the output can be reduced from its nominal value when I=0 to V_O Nominal - 10% V_O Nominal (RX is not installed). To calculate the value of R, at least one of the resistors, RF or R_{IN}, must be known. Resistor RA does not appear in Eq.2.

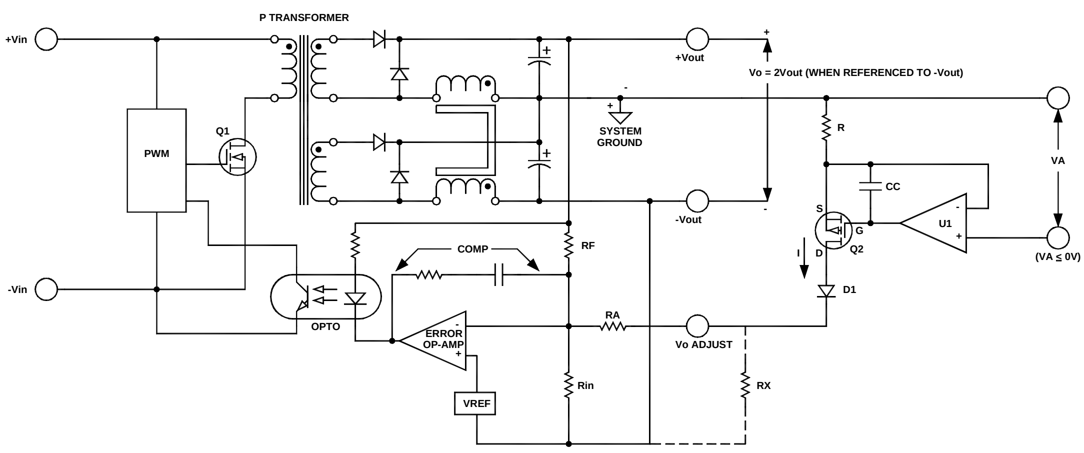

FIGURE 2. Adjustable bipolar output DC/DC converter using a current source, with the error OPAM reference connected to -V_{OUT} and the current source connected to system ground. (NOTE: The current source can be referenced to +V_{OUT} by connecting R to +V_{OUT}.

Referring to Figure 2, under ideal conditions the -input of the error amplifier must be at the same voltage as the positive input. Summing the currents at the -input of the error amplifier, we can write the following equation when $-V_{OUT}$ is used as our zero reference point:

$$\frac{V_O - V_{REF}}{RF} + I = \frac{V_{REF}}{R_{IN}} \qquad \text{Eq.3}$$

Solving for I, we get:

$$I = \frac{V_{REF}(R_{IN}+RF) - V_O * R_{IN}}{R_{IN} * RF} \qquad \text{Eq.4}$$

NOTE: V_O in Eq.4 is the new lower value needed of V_O.

EXAMPLE 1: A $\pm 15V_{OUT}$ converter must be adjusted lower by 10%, given RF=27.5kΩ, R_{IN}=2.5kΩ and V_{REF}=2.5V, find the needed current I:

From Eq.4: I(mA) = (2.5(2.5+27.5) - 27(2.5))/(2.5*27.5) = (75-67.5)/68.75 = 0.1091mA

The current through (RF-R_{IN}) when V_O=30V is:
30V/30kΩ=1mA

Lowering V_O by 10% (from 30V to 27V), we calculate that we need a current of 0.109mA, which is approximately 11% of 1mA. If $+V_{OUT}$ was used to trim V_O lower to 27V or ±13.5V, we can calculate the external resistance, which would be connected from V_O to the V_O Adjust pin.

Using the calculated current I from Eq.4:

$R_{EX} = (V_O - V_{REF})/I$ = (27-2.5)/0.000109 = 224.771kΩ

NOTE: When RA is installed, it must be subtracted from R_{EX}.

When the output V_O needs to have an adjustment range of ±10% of V_O Nominal, RX must be installed. In standard converters, designers select RA such that when V_O Adjust is connected to the $-V_O$ or the negative reference point, the maximum value of V_O is obtained. If RA is calculated for a maximum of 10% when V_O Adjust is shorted to $-V_O$ ($-V_{OUT}$) for bidirectional adjustment, the value of RX is limited as well as the output adjustment of the bidirectional range. Assuming RA is set for V_O Max = V_O Nominal + 10%, RX can be set equal to RA for V_O Max = 1.05% or lower (down to a few ohms).

Keep in mind the current I provided by the current source must generate a current going through RX, such that: **$I*RX \geq V_{REF}$**.

EXAMPLE 2: Given RX=100Ω and RA=20kΩ, calculate the V_O Max and I*RX needed using the same converter values from Example 1.

New $R_{IN}{}'$ = R_{IN}||20.1kΩ = (2.5*20.1)/22.6 = 2.223kΩ

V_O Max = ((RF/R_{IN})+1)V_{REF}) = ((27.5/2.223)+1)*2.5) = 33.43V

From Example 1, the current I going into the summing point from the current source is I=0.109mA, which gives V_O=27V.

Therefore:
RA*0.109×10^{-3}+2.5V = VRX
$(20\times10^{3})*(0.109\times10^{-3})+2.5$ = 4.68V
and IRX = 4.68/100 = 46.8mA which is not practical!!!

Selecting RX=1kΩ will give V_O Max=33.3V and IRX=4.68mA. The diode D1, in series with the drain of Q2, will prevent any current from flowing back in the drain of Q2 at turn on. In converters with high output voltage V_O > 100V, select Q2 for high V_{DS} and low leakage current. Also note the current source and VA is referenced to system ground; the $+V_{OUT}$ ($+V_O$) can be used, but you need a higher voltage rating for Q2, and VA must track $+V_{OUT}$.

DUAL ISOLATED OUTPUT DC/DC CONVERTERS

Isolated dual output DC/DC converters provide the customer with design flexibility and eliminate ground loops. As shown in Figure 3A, the auxiliary output is semi-recalculated through L_O, and depends not only on the magnetic coupling of the power transformer and L_O, but also on both main and auxiliary loads. The converter in Figure 3A requires a minimum load at its main (regulated) output in order to energize the feedback loop and force the PWM to increase its duty cycle.

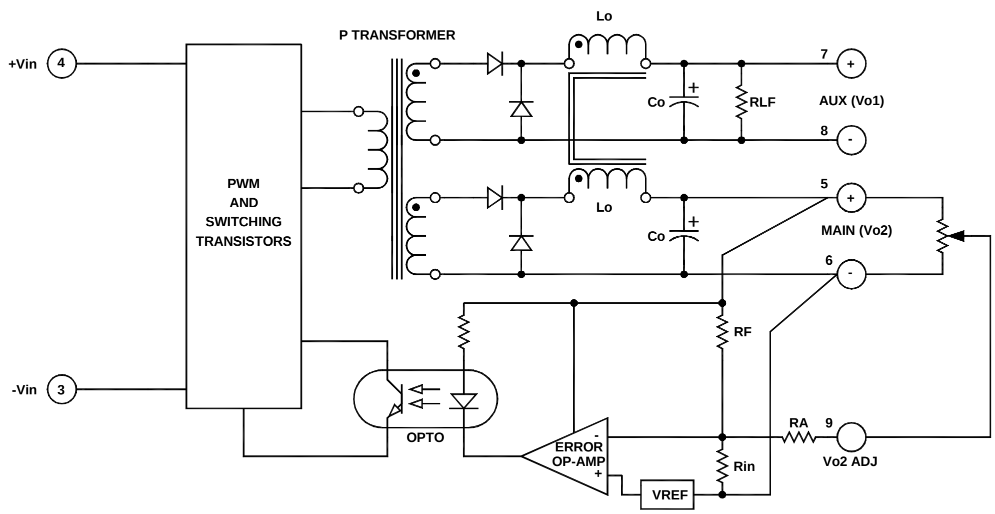

FIGURE 3A

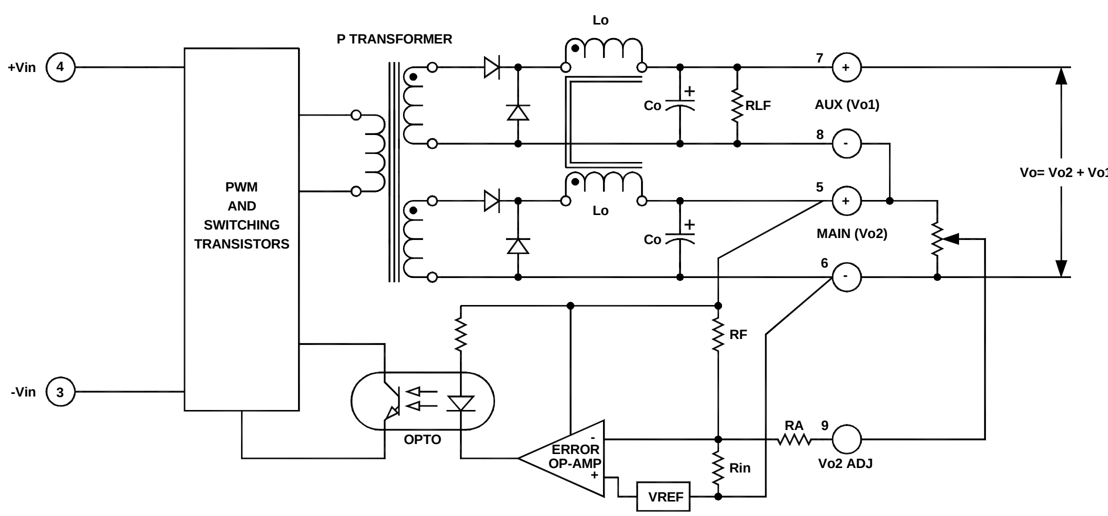

FIGURE 3B. Isolated dual output DC/DC converter with AUX output connected in series with MAIN output for higher V_O

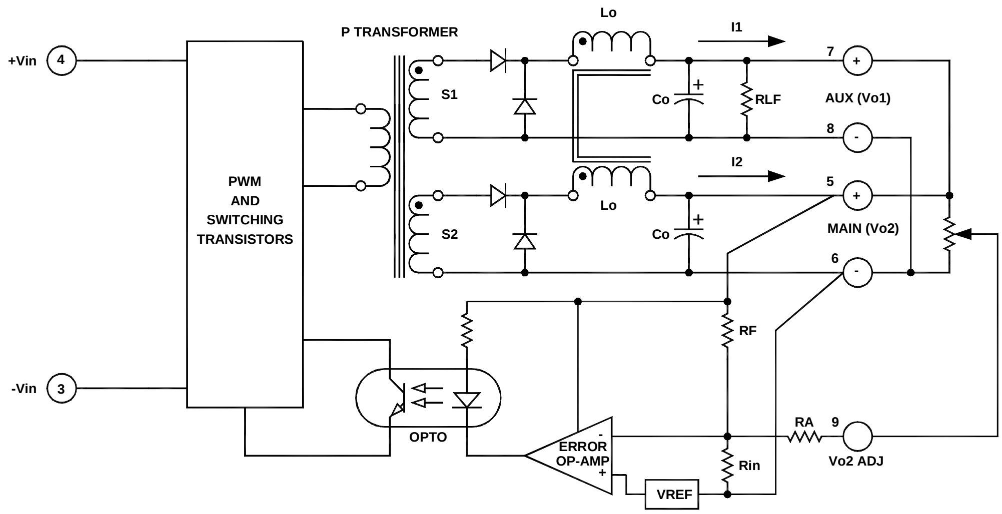

FIGURE 3C. Dual isolated output DC/DC converter with parallel connected outputs for higher I_O
I_O=I1+I2 with equal secondary turns

The auxiliary output is preloaded by RLF and an overvoltage zener diode to prevent any overvoltage condition in case the external load is not installed or disconnected. The converter in Figure 4 is the same converter given in Figures 3A, 3B and 3C with one exception: it incorporates output synchronous rectification for its main output. The converter in Figure 4 does not need a preload for its main output due to the fact that the loop is energized by the switching loss in the MOSFETs. Typically, the converter in Figure 4 has higher input current than that of Figures 3A, 3B and 3C under a no load condition. When the two outputs are connected in series for a higher output voltage or a bipolar (±) output, the output adjustment (of both outputs) is implemented through external resistors, potentiometers, or active devices. Figures 3 thru 6 show different DC/DC converters and output connection combinations.

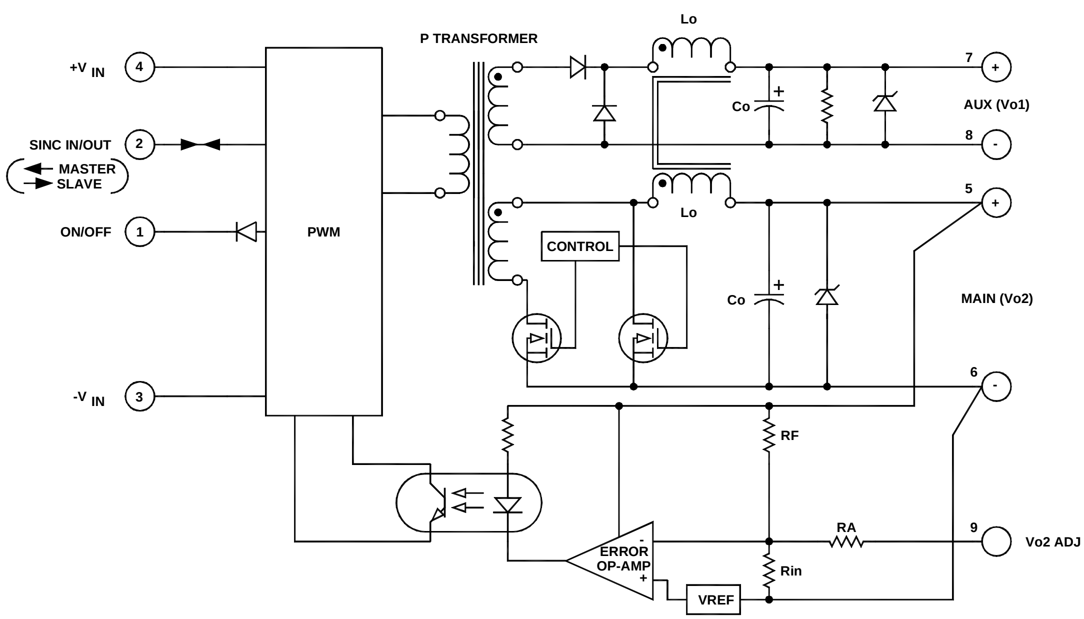

FIGURE 4

Keep in mind when active devices (D/A, OPAM, and current sensors) must be used, the reference point of the voltage reference to the error amplifier must be used. For example, in Figure 3 the reference point is the negative main output (Pin 6). Beta Dyne's converters with dual bipolar outputs usually have the error amplifier's voltage reference connected to the $-V_{OUT}$ pin. Unless we specify otherwise, the internal voltage reference is the pin where the external trim resistor must be placed to **increase V_{OUT}**. ***It is not the V_o Adjust pin.***

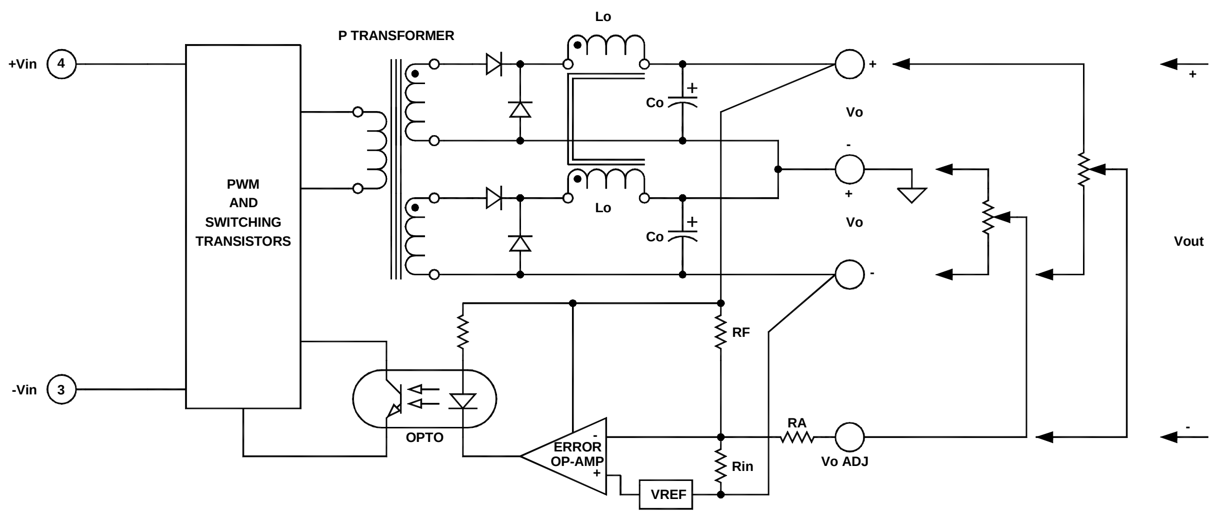

FIGURE 5. Bipolar output converter with the error OPAM referenced to $-V_{OUT}$

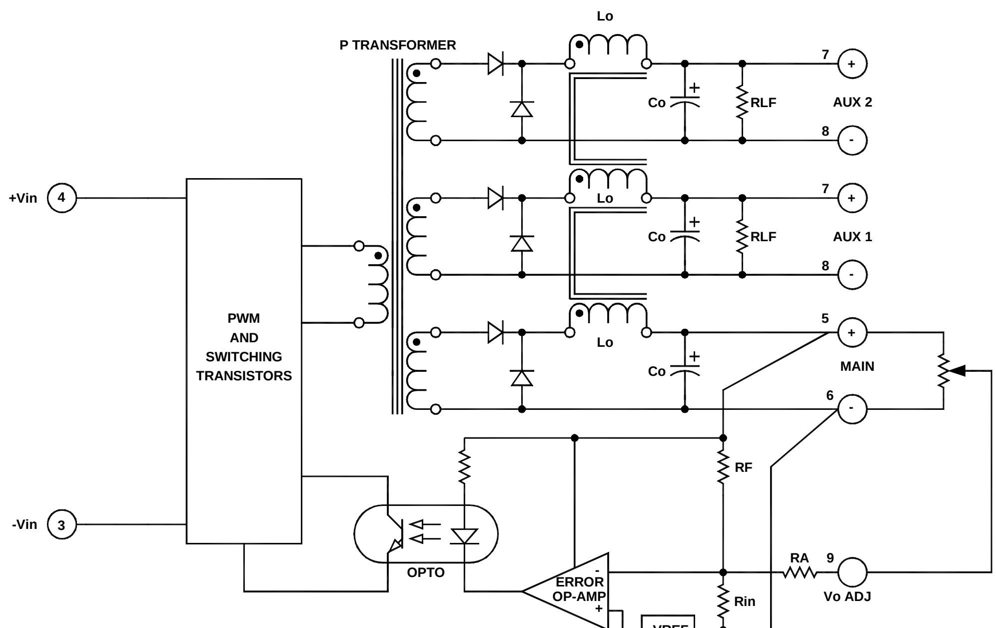

FIGURE 6. Triple isolated DC/DC converter with AUX 1, AUX 2 semiregulated through L_O