

LM2585,LM2593HV,LM2651,LM324

It's a Buck; It's a Boost, No! It's a Switcher! (part four)



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Technology Edge

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By Sanjaya Maniktala, Application Engineer

Differential Voltage Sensing

Returning to some of the issues in Part 1 of this article, in [Figure 11](#) and [Figure 12](#), a crude voltage dependent current source was used for output regulation. As mentioned, a more accurate sensing scheme for better output regulation can be implemented by using an op-amp (like the [LM324](#)). There are two ways of setting up such a differential amplifier. They are shown in [Figure 23](#) and [Figure 24](#). They are respectively alternatives to [Figure 11](#) (negative to positive Buck-Boost using Type 1 IC), and [Figure 12](#) (negative to negative Buck using Type 1 IC). Note that the inputs to the op-amp are labeled V_{o_hi} and V_{o_lo} .

This means that irrespective of how the schematic actually labels them, i.e., which is V_o (or $-V_o$) and which is ground, these nodes must connect to the upper and lower output rails respectively. Some of the relevant aspects of op-amps must be kept in mind. For example, note that an op-amp has a specified input voltage common mode range. For the LM324 series this number is specified to be 1.5V below the upper supply rail and this parameter is hereby called v' in this article. We require that the voltage on both the input pins of the op-amp stay within this allowed range, or the op-amp cannot be considered fully functional. Since the voltages on these pins are fixed by virtue of the resistors, if the resistors are considered fixed, the only way is to ensure that the common-mode condition is met is to set the op-amp supply rail V_{aux+} sufficiently higher. This limit equation is therefore also provided in [Table 4](#). Note that if the required minimum V_{aux+} value, is still low enough, it may be possible to connect it to an available DC rail. If not, an additional external rail will need to be created to run the op-amp stage.

[Figure 24](#) provides much higher gain (if required) and is suited for very low output voltages. If [Figure 23](#) does not work, [Figure 24](#) can be tried for more flexibility. The relevant equations are summarized in [Table 5](#).

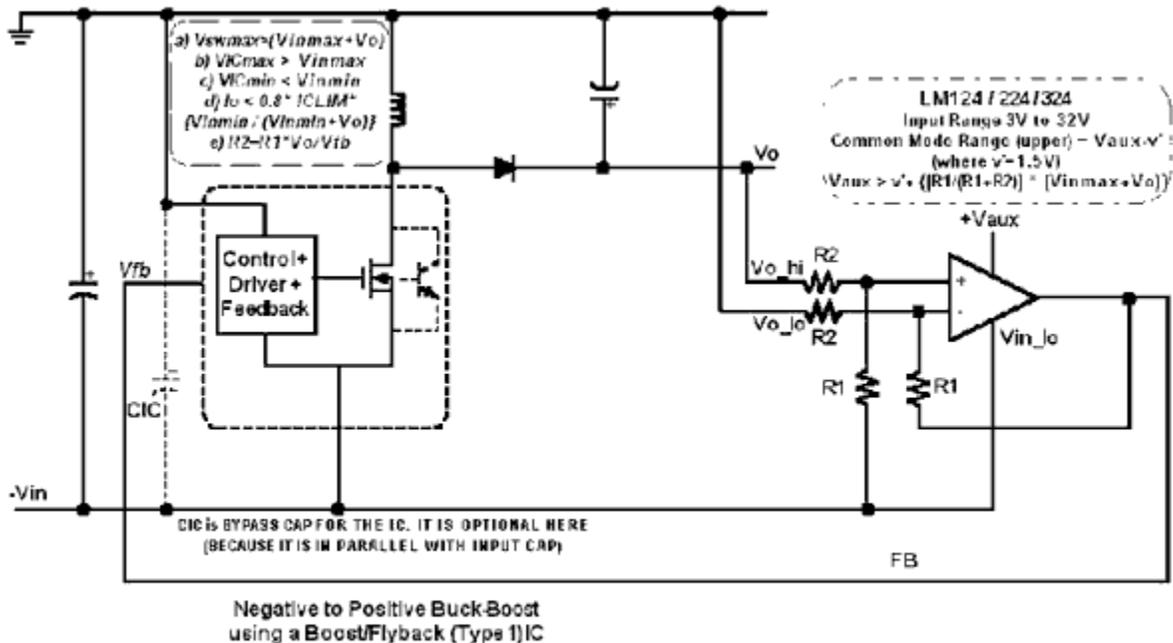
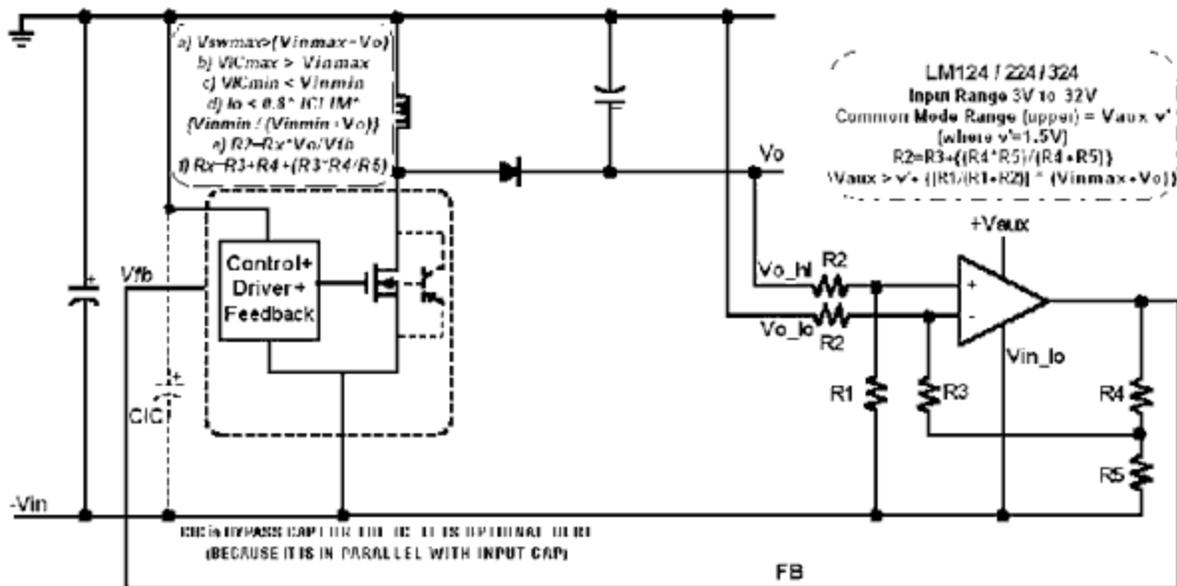


FIGURE 23



Negative to Positive Buck-Boost using a Boost/Flyback (Type 1) IC

FIGURE 24

Table 5: Op amp choices

Figure	Op-Amp	Equation Set
Fig 23	Standard Differential Amp.	$R_2 = R_1 \cdot V_o / V_{fb}$ $V_{aux} \geq v^* + \left[\frac{R_1}{R_1 + R_2} \cdot (V_{in\ max} + V_o) \right]$
Fig 24	Hi-Gain Differential Amp.	$R_2 = R_x \cdot V_o / V_{fb}$ $R_x = R_3 + R_4 + \frac{R_3 \cdot R_4}{R_5}$ $R_2 = R_3 + \frac{R_4 \cdot R_5}{R_4 + R_5}$ $V_{aux} \geq v^* + \left[\frac{R_1}{R_1 + R_2} \cdot (V_{in\ max} + V_o) \right]$

Some Practical Cases

We now present some typical examples to clarify the procedure further.

Example1: The LM2585 is a '3A Flyback regulator'. The datasheet is available at <http://www.national.com/ds/LM/LM2585.pdf> for more details.

The MIN value of its internal current limit (see its Table of Electrical characteristics) is 3A. Its input operating voltage range is 4V to 40V. Its switch can withstand 65V. Can it be used in a Boost topology? And for what applications?

The following steps are required in this analysis.

1. We identify that the LM2585 is a Type 1 IC by our nomenclature.

- Referring to the summary chart for Type 1 in [Figure 18](#) (Part 1 of this article), we see that it can be used as say a positive to positive Boost. The corresponding figure is [Figure 10](#) (in Part 1 of this article).
- Now we consult [Figure 10](#) (Part 1 of this article). This is the required schematic. The feedback scheme is noted. For more detailed design equations for this topology one can refer to the design table under 'Boost' in [AN-1246](#).
- The relevant selection criteria for suitability are in [Table 4](#). We read off the equations corresponding to [Figure 10](#) in this table and we get the following checklist

$V_{sw\ max} \geq V_o$	$I_o \leq 0.8 \cdot I_{CLIM} \cdot \frac{V_{in\ min}}{V_o}$ $R2 = R1 \cdot \left[\frac{V_o}{V_{fb}} - 1 \right]$ $D_{max} \geq \frac{V_o - V_{in\ min}}{V_o}$
$VIC_{max} \geq V_{in\ max}$	
$VIC_{min} \leq V_{in\ min}$	

- We see that the input voltage must be below 40V and the output voltage must be below 65V (since $V_{swmax} > V_o$ and $VIC_{max} > V_{inmax}$). These define the input/output voltage conditions for any suitable application.
- The maximum load current is

$$I_o = 0.8 \times I_{CLIM} \times \left[\frac{V_{in\ min}}{V_o} \right]$$

So if the output is set to 60V and the input ranges from say 20V to 40V, the maximum load (with a suitably designed practical inductor) is

$$I_o = 0.8 \times 3 \times \left[\frac{20}{60} \right] = 0.8A$$

Example2: The required application conditions are V_{in} ranging from 4.5V to 5.5V. The output requirement is -5V at 0.5A. Can the LM2651 be used?

LM2651 is a '1.5A Buck Regulator'. Note firstly that this IC can deliver 1.5A in a Buck configuration, but not so in any other configuration/topology. The load rating must then be re-calculated. The following steps are performed.

- We identify the LM2651 as a Type 2 IC according to our nomenclature
- We refer to [Figure 22](#), which summarizes all the applications of Type 2 ICs. We can see that a positive to negative Buck-Boost is possible with this IC.
- The relevant schematic is stated to be [Figure 20](#) which we consult for the schematic and feedback scheme.
- Referring to [Table 4](#) for the selection criteria corresponding to [Figure 20](#):

$VIC_{max} \geq V_{in\ max} + V_o$	$I_o \leq 0.8 \cdot I_{CLIM} \cdot \frac{V_{in\ min}}{V_{in\ min} + V_o}$ $R2 = R1 \cdot \left[\frac{V_o}{V_{fb}} - 1 \right]$ $D_{max} \geq \frac{V_o}{V_{in\ min} + V_o}$
$VIC_{min} \leq V_{in\ min}$	

- Referring to the datasheet of this device at <http://www.national.com/ds/LM/LM2651.pdf>
 $VIC_{min}=4V$
 $VIC_{max}=14V$
 $ICLIM=1.55A$
- Therefore we now check sequentially for these conditions:
 - $VIC_{max} > V_{inmax} + V_o$ $14V > 5.5V + 5V = 10.5V$ OK
 - VIC_{min}

c) $l_o < 0.8 \cdot I_{CLIM} \cdot (V_{inmin} / (V_{inmin} + V_o))$ $0.5 < 0.8 \cdot 1.55 \cdot \{4.5 / (4.5 + 5)\} = 0.587$ OK

The maximum duty cycle can be as low as 92%.

Checking for this too:

d) $D_{max} > V_o / (V_o + V_{inmin})$ $0.92 > 5 / (5 + 4.5) = 0.53$ OK

Therefore the LM2651 is acceptable for the intended application.

Other Concerns in Topology jumping

One of the main concerns when we jump topologies has to do with a nuance of the topologies themselves. In particular, we must remember that a Buck topology has no Right Half Plane ('RHP') zero, but the Boost and the Flyback/Buck-Boost do. Therefore when we try to take a Buck IC (with internal fixed compensation), we may not have the ability to tailor the crossover frequency to less than 1/4th of the RHP zero frequency as is generally recommended for avoiding this particular mode of instability. So how do we successfully take a Type 2 IC and apply it to other topologies?

To answer that we first must remember the 'intuitive explanation' behind the RHP zero. This is said to occur as follows. If we suddenly increase the load on the output of a Boost or Buck-Boost regulator the output dips momentarily. The voltage on the feedback pin therefore falls slightly and this commands the duty cycle to increase to try and correct for this. But both the Boost and the Buck-Boost are different from the Buck in that during the switch ON-time, NO energy flows into the output...we are basically just building up energy in the inductor during that time. So if the duty cycle increases in response to the load increase, in fact there is a smaller OFF-time, and therefore less rather than more current flows into the output. This causes the output to decrease further. Eventually, after a few cycles, the average inductor current does ramp up progressively and the output dip gets corrected. But before that happens, we can see a situation where the load disturbance is reinforcing itself. In severe cases this may lead to sustained oscillations.

Two well-known RHP zero suppression techniques are used when using a Buck IC to generate other topologies. We show them as applied to a positive to negative configuration. One is shown in [Figure 25](#). This sense when the duty cycle increases suddenly and it thereby pushes up the feedback pin slightly so that it doesn't dip too low in response to the sudden load demand. In [Figure 26](#), we have a typical application circuit as reproduced from the datasheet of LM2593HV, (at <http://www.national.com/ds/LM/LM2593HV.pdf>) and we compare the additional components introduced with the schematic in [Figure 20](#). Basically a diode has been inserted and the IC bypass cap is sized to be much bigger now. It is no wonder that the schematic looks much closer to a Buck rather than a Buck-Boost. And in fact during a load transient it does behave temporarily as a Buck, because now significant energy can be transferred from CIC to the output during the switch ON-time. This suppresses the RHP zero significantly, though as compared to [Figure 25](#) it does introduce additional losses across the input diode.

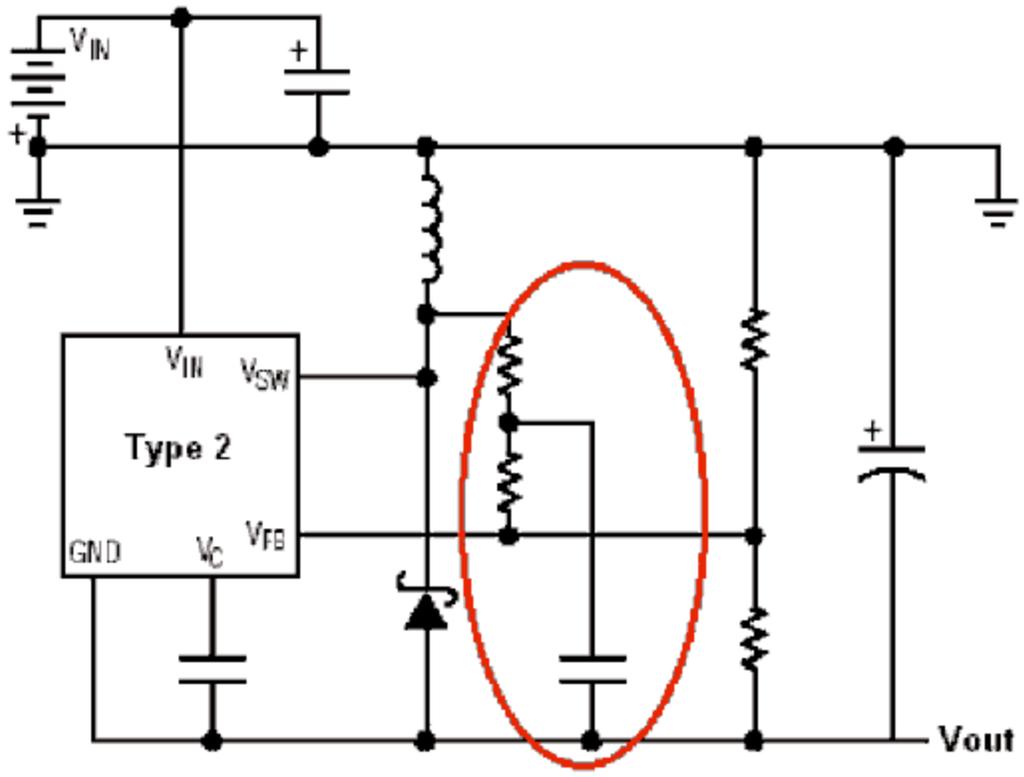
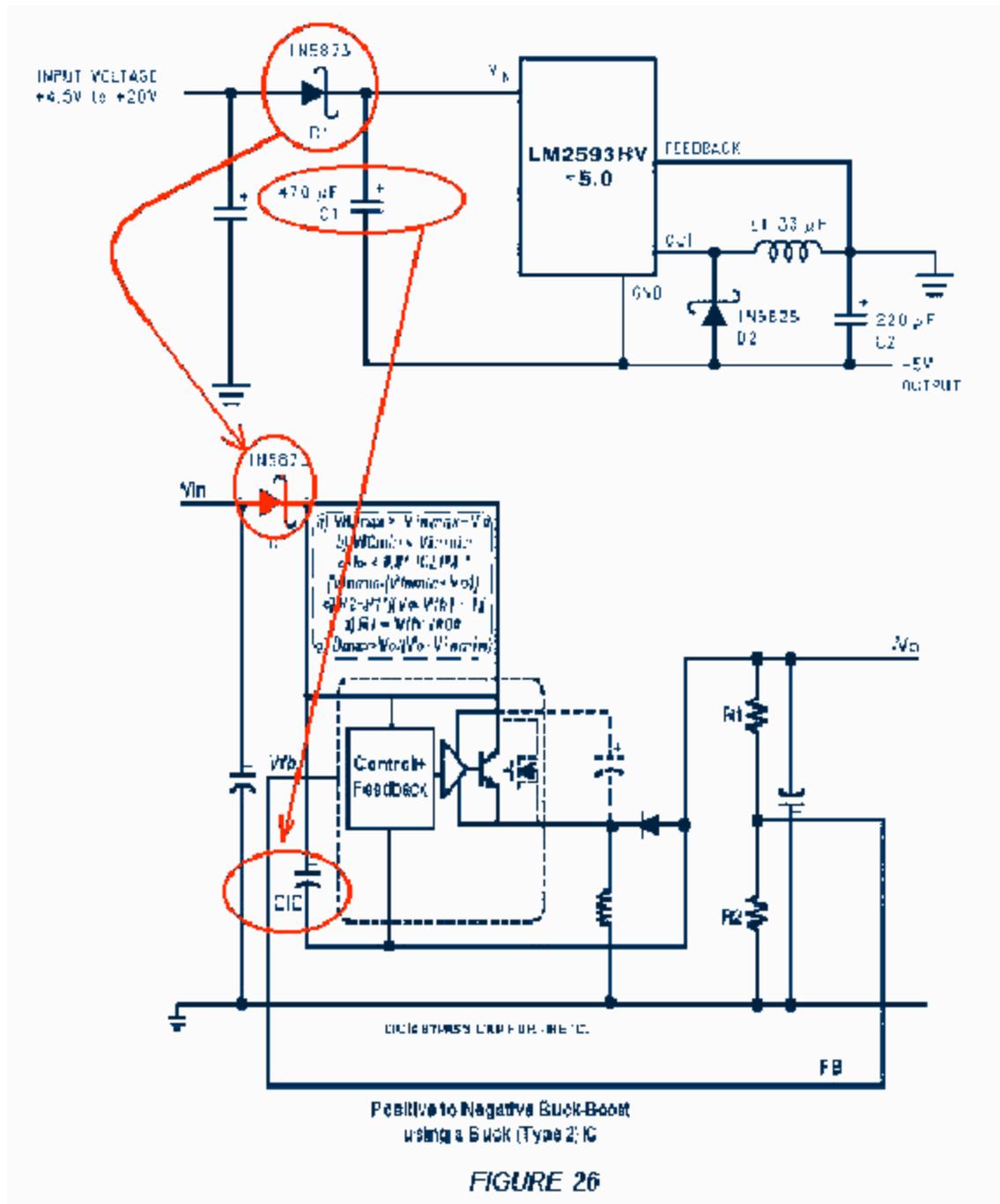


FIGURE 25



References

- Application Note AN-1197 at <http://power.national.com>
- Application Note AN-1246 at <http://power.national.com>

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To contact the author, email: sanjaya.maniktala@nsc.com

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