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Low Output-Voltage CATV Flyback Converter (Continued)

We continue the questions from a 5 W flyback converter designer working on a CATV application.

Converter Input/Output Isolation

"Dear Dennis:

The converter input is CATV, for which one side is hard ground, so an isolated supply is needed. The voltage-sense input using a half-wave rectifier is tickling off such a light current that I am "cheating" that directly from the input."

Dennis Responds:

Be aware that what is really being presented to your monitoring circuitry is the input voltage plus the difference in voltage between the two (isolated) grounds, and that could be both hard to predict and substantial in value.

"I have looked at capacitively-coupled designs for deriving a few tens of milliwatts from the line, but I did not think I could get away with this drawing 5 W. The cable guys aren't happy if one pulls power from only one half of the power cycle, as this causes galvanic funny business at points between the load (us) and the power supply (possibly a mile away or so) that they seek to avoid by using ac power in the first place."

This is a valid reason for avoiding capacitive-divider voltage-reducing supplies. They can be used for *non*-isolated (ac-isolated, that is) supplies of under 1 W.

Output Capacitor ESR

"Given the wide voltage range and wide temperature operating range (-40°F to +150°F) we might wish to avoid a design that has stability issues. You probably are aware that low ESR aluminum electrolytics such as the Panasonic FC series can go to 40 × the room-temp ESR when taken to 40 below. There are other cap technologies such as tantalum and polymer, but these have serious cost issues and this is a cost-sensitive design, as is everything to do with CATV."

Variation in *equivalent series resistance* (ESR) is a problem for most converter feedback circuits because the variable R of the capacitor shifts the feedback-loop zero around. If your design has this large variation in ESR, be sure to analyze it at the extremes of R for phase margin. If R becomes too small, the zero can shift out of its useful range and lead to inadequate stability margin too.

Be wary of subjecting tantalum capacitors to high ripple currents. They cannot take it, and the manufacturers usually recommend adding series resistance to protect against current-surge shorts, thereby defeating the value of bypassing. For the higher-switching frequencies found nowadays, ceramic capacitors are a good choice, though somewhat expensive.

Planar Magnetics

"I do not plan to use a planar transformer as a component but rather use roughly $0.25 worth of ferrites clamped directly through my primary circuit-board, so that my own PCB traces form the windings of the

transformer. I am doing this in order to minimize cost, as I don't believe I can get a custom SMD transformer for much less than a $2 - 3 in my anticipated volume (5000 - 10,000 per year)."

This is, in effect, a planar transductor integrated with a circuit-board. You might easily achieve your cost goal through suppliers from Asia. I would go with a non-ECB-based transductor that mounts as a component on the board. The board-integrated kind are best when you're pushing the state of the art, well above 500 kHz. Otherwise, your scheme is not a bad choice, though it has as much or more in labor (assembly) cost than buying a finished component.

In the flyback converter transductor, I assume a worst-case coupling for the windings of $k = 0.98$. For a 5-W implementation that is probably fairly accurate. For flyback topology, k does not affect performance too much, but loose coupling can create objectionable noise and conversion problems in other types of converters.

"I would appreciate it if you could point me to someone who can make custom transformers cheap. With the number of windings I need to incorporate, it may be a challenge to get my entire transformer on a 4-layer board. With 6 it would be a piece of cake, but then my boards would be more expensive."

There are many magnetics "houses" about the North American continent. I can recommend Z-man Magnetics in Oregon and Washington. They are the spin-off of the Tektronix magnetics group of many years ago and they not only are technically competent, but are excellent to work with: just down-to-earth Tek engineers. They were just recently acquired by http://www.hirelsystems.com (under Specialty Products).

Another magnetics supplier with whom I have worked is closer to you and is also recommended: DT Magnetics in NC. My contact there is Ben Thorson. bthorson@DTMagnetics.com Send Ben a copy of your transductor spec for a quote and prototype samples. In this industry, prototyping samples are usually provided at no charge.

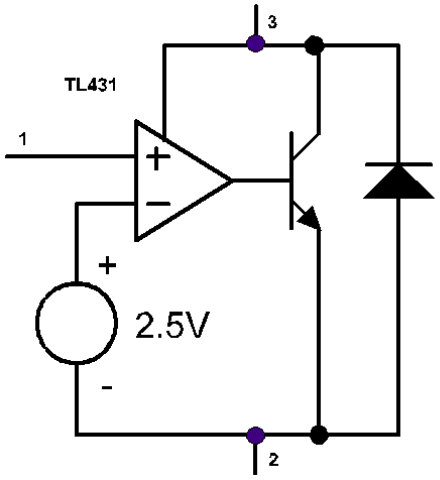
For low cost, as well as samples, you might go to China, through CUI in Beaverton, OR (contact Don Li dli@cui.com) a company that imports Asian magnetics into North America. Don has a PhD in power electronics, which helps in discussing your magnetics requirements. The Chinese prices for magnetics are astoundingly low (less than half US prices) and their turnaround time for samples is fairly quick too.

Although CATV is cost-sensitive, reliability is also a cost factor during product life. Your flyback converter should be very reliable as long as the board-based transductor is mechanically solid. At least with board-trace windings, they won't buzz! (They could possibly delaminate from the board, however, because of Lorentz forces on the windings.) For such low power, winding loss shouldn't be much of an issue.

3.3-V Ouput and the LM431

"I've found a hitch in my design that I did not expect, and am writing to see if you've seen this before. I am trying to get a tightly regulated +3.3 V output. The resistor values I'm using should produce this, but the supply "blinks," puts out juice, then shuts down with about a 100 ms on, 600 ms off, cadence. I think the issue is the LM431 and optoisolator. The opto drops about 1.1 V across its LED when in stable operation in this circuit. (Adding the 2.2 MΩ or so pull-down resistor from base to ground in the optoisolator phototransistor would probably make LED drop higher still.) Operating at +3.3 V leaves less than 2.2 V across the LM431 when resistor drops are accounted for, and I'm not sure how happy this part is when the cathode is operating below the reference potential. National specs say the part should operate properly from a V_{ref} of 2.5 V up to 36 V, but they do not say what will happen below this. My guess is that all bets are off, that the regulation might not be so good, the temperature compensation may not work properly, and operating variations from part to part may be large."

My working diagram for the LM431 or TL431 is shown below. A bandgap reference drives the inverting op-amp input. Any voltage at pin 3 below 2.5 V is going to leave the op-amp with insufficient operating voltage and a transistor or two in the op-amp will saturate. With only 2.2 V at pin 3, there is bound to be trouble.



"I am going to try powering the cathode from my higher, +12 V supply, and that should take care of the problem. I also recognize that, for establishing $V_{ref,}$ I can tap some current from +12 V, some from +3.3 V, and have the voltage regulation be somewhat more tightly linked to both. This was an unexpected kink in the design, and I thought I'd pass along my findings so that, should you encounter this again in the future (with smaller geometries, many ICs are moving to +1.8 V, +2.2 V, and so on), you would have thought it through already."

Make sure that the +12 V supply will reliably come up at power-on so that no bootstrapping problem occurs -- that is, the +3.3 V output must not need to come up first to bring up the +12 V supply. Also at power-on, make sure that the supply sequencing does not lead to transient overvoltaging on the +3.3 V supply. This might occur if the +12 V supply is delayed too long, causing the +3.3 V supply error to be large in the direction of commanding more voltage.

Later, the reader came back with the following comments:

"Splitting the LM431 circuit did the trick: ref from 3.3 V, opto from +12 V. This was also the easiest to hack out on the circuit board."

Ah, good! The LM341 op-amp now has enough headroom and it works properly.

"I believe the LV version of the LM431 would do the trick also, running solely off of 3.3 V, but I haven't tried it to confirm. No reason to do so at this point. The thing runs well, but runs in little "boost groups," turning on and switching for a while, with peak current ramping up a little in each pulse, then a short cycle at the end, then off for an even longer time, this at a 12 kHz or so rate. This is probably the light-cycle operating mode, the LM5021 shutting down when voltage on the feedback input drops too low. I haven't tried loading it more heavily so see. I know that the part has a cycle-skipping mode to keep it efficient when it is lightly loaded."

That would be my guess too. Light loading is a problem for switcher control generally because there is a minimum duty ratio determined by the current-loop delay time. The only other variable (degree of freedom) is switching frequency, and cycle skipping merely halves (or reduces) it.

"I am not actively working on the project at this time, just finishing things off for a handoff to production for a run of 100 or so. So no further funding."

Glad you got it to work for the first build!

"Best regards and thanks for your input on the switcher and magnetics. That saved me a lot of time and trouble.

"I looked over your package and, yes, it is most certainly worth the $250 -- A very thorough write-up in the Word document; many thanks. This is an education as well as a review."

Readers, I do design reviews that go beyond what can be addressed here in the analog ZONE Design Clinic for a fixed fee of $250 US. I did one on the flyback supply for this reader and he liked what he got. For this amount of review, I look through the design and say everything I can (including some design calculations, if relevant) that might help you to improve your design, with explanations for why it should. See http://www.innovatia.com (Design Assistant) for details.