**LM3419 True Zero Application Analysis:**

## April 12, 2012

**Descriptions:**

LM3419 is a synchronous buck controller for precision dimming. Its target analog dimming ratio is 500:1. In order to achieve such high dimming ratio, chopper OTA is designed to minimize the offset. Also, an external resistor from VLED to CS pin is required for true zero application.



1. **The Use of Chopper OTA to Minimize the Offset:**

LM3419 adopts constant on-time control scheme. The on-time depends on the VIN and VLED conditions. The off-time is determined by the control loop. In order to minimize the offset, a chopper OTA is used. The non-inverting and inverting inputs and outputs interchange to cancel the offset in alternate cycle.

With the chopper OTA, the input offset voltage of the error amplifier is less than ±500µV (To be confirmed with tri-temp ATE data).

1. **Why Need an External Resistor?**

In true zero application (VIADJ=0V), there will be certain amount of ILED even the inductor current is well-regulated at 0A (assume there is no offset at the OTA).

An external resistor from VLED to CS is added to shunt the +ve current ripple, so that there is no ILED while maintaining the operation of chopper OTA to cancel the offset. The dc shift should be at least half of the IL ripple.

$$I\_{OFF}=\frac{VLED}{R\_{OFF}}×\left(\frac{R\_{CS}}{R\_{SNS}}\right)>0.5×∆ILED$$$$ R\_{OFF}<\frac{VLED}{(0.5×∆ILED)}×\left(\frac{R\_{CS}}{R\_{SNS}}\right)$$



iOUT= iOFF+iC+iLED

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During start-up, VLED increases linearly according to the resistor divider ratio set by ROFF, RCS and RSNS. With further increasing VLED, there will have ILED when VLED is just higher than the forward voltage of LEDs.

This is the simulation result with two LEDs and ROFF=240kΩ.



 

It can be observed that there is ~10mV at VCS when it starts to have ILED. This offset voltage creates a delta voltage between IADJ and CS pin and hence switching occurs. The chopper OTA works and the OTA offset becomes insignificant.

Assume the offset of a general OTA is <±10mV, the VCS voltage must be >10mV before VLED>Vf.

$$VCS=VLED×\left(\frac{R\_{CS}+R\_{SNS}}{R\_{OFF}+R\_{CS}+R\_{SNS}}\right)>10mV$$$$R\_{OFF}<\left[VLED×\left(\frac{R\_{CS}+R\_{SNS}}{10m}\right)-(R\_{CS}+R\_{SNS})\right]$$

ROFF actually creating an offset on the regulated ILED level, so there will have a fixed offset in ILED independent of VIADJ level. The offset in ILED will be:

$$I\_{OFF}=\frac{VLED}{R\_{OFF}}×\left(\frac{R\_{CS}}{R\_{SNS}}\right)$$

**Bench Measurement Results:**

Conditions: VIN=12V, #LEDs=2, RCS=470Ω, RSNS=0.2Ω, COUT=1µF, ILED ripple=50mA

It can be observed that the true-zero point increases with reducing ROFF. Here are some waveforms with different VIADJ levels. Switching occurs all the time.

|  |  |  |
| --- | --- | --- |
| VIADJ=0mV | VIADJ=6mV | VIADJ=100mV |
| print_004.bmpROFF=560kΩ**SW****ILED** | print_003.bmp | print_002.bmp |

With 560kΩ from VLED to CS creates a 25mA offset in ILED, it can be observed that there is fixed 25mA shift in ILED in whole range of VIADJ.

**Conclusions:**

An external resistor (ROFF) from VLED to CS pin is required for true zero application, where ROFF should be

$$ R\_{OFF}=min\left[\frac{VLED\\_min}{(0.5×∆ILED)}×\left(\frac{R\_{CS}}{R\_{SNS}}\right),\left[VLED\\_min×\left(\frac{R\_{CS}+R\_{SNS}}{10m}\right)-(R\_{CS}+R\_{SNS})\right]\right]$$