Start-Up Test Using Electronic Load

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1. Introduction to Electronic Load

Electronic loads, such as Chroma 6310 series, can be configured as constant current (CC) mode, constant voltage (CV) mode and constant resistance (CR) mode. In CC mode, the load will sink a current in accordance with the programmed value regardless of input voltage. In CV mode, the load will sink current to control the voltage source in programmed value. In CR mode, the load sinks a current linearly proportional to the input voltage in accordance with the programmed resistance. Internal feedback control circuit controls the load current based on its mode set up and input voltage.

A simplified electronics load diagram is shown in Figure 1. Use CC mode as example, I_{set} is the load current set value. I_{sense} is the actual load current sense signal. The feedback circuit consists of error amplifier and feedback network Z_f. The amplifier compares the I_{set} and I_{sense}, the output signal is used to control power transistor Q1 base voltage. As a result, the power transistor Q1 only pulls current I_{load} equal to I_{set}, into the electronic load. When $I_{load} < I_{set}$, feedback circuit will turn on Q1 harder to pull more current until $I_{load} = I_{set}$. When $I_{load} > I_{set}$, feedback circuit will turn on Q1 less to pull less current until $I_{load} = I_{set}$.

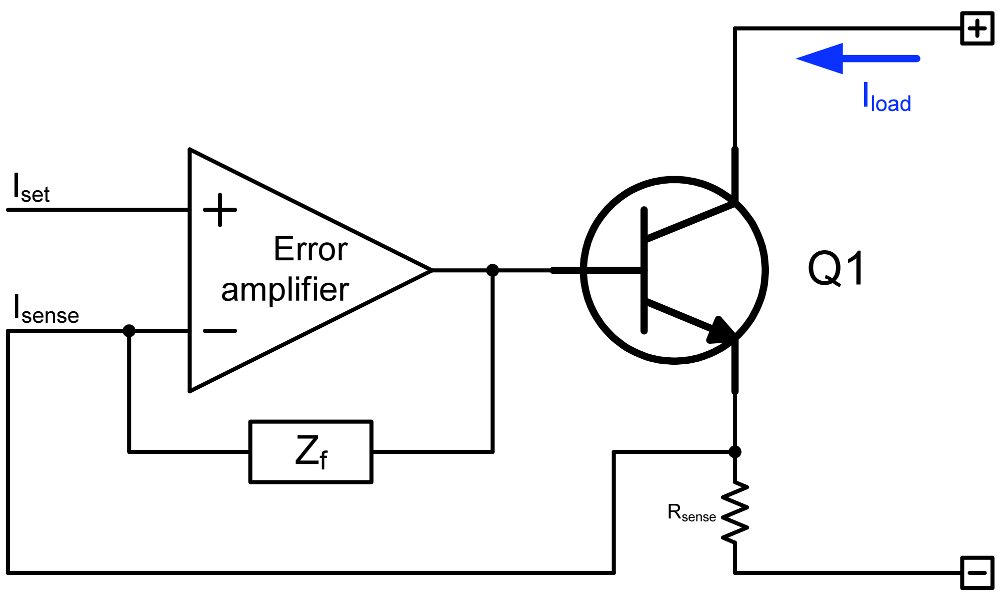

Figure 1: Simplified electronics load diagram

Besides operation modes, there are other parameters that need to be programmed before each use. They are Turn-on Voltage (Von), Von Latch switch and Slew Rate, etc. The electronic load starts to sink current when the input voltage reaches Von voltage. Enabled Von latch means the load will sink current continuously when the input voltage reaches Von voltage. Disabled Von latch means the load will stop sinking current when its input voltage is below Von voltage level. The slew rate is defined as current change over time. Regardless the input voltage, the load will sink current at programmed slew rate.

2. Why Can't Some Buck Regulators Start Up Using Constant-Current Mode of Electronic Load

When using electronic load set in CC mode, avoid to set turn on voltage to 0V. For example, electronic load current is set to be 2A and electronic load turn on voltage is 0V. Then the electronic load input impedance is:

$$R_{E\_load} = \frac{0 \cdot V}{2 \cdot A} = 0 \cdot \Omega$$

When using this electronic load for start up test, the electronic load is ON before converter turns ON, the actual load impedance connected to the output of converter is 0Ω. From Figure 1 above, the I_{set} value is 2A but I_{sense} is 0V at this moment. The electronic load internal feedback circuit is saturated. The base of transistor Q1 is HIGH and Q1 is fully ON.

The converter under test will try to start up while its output is shorted. The result shown in Figure 2 is that circuit operates in short circuit protection mode. The output can only ramp up to a minimum level due to the reduced operating frequency in short circuit protection mode.

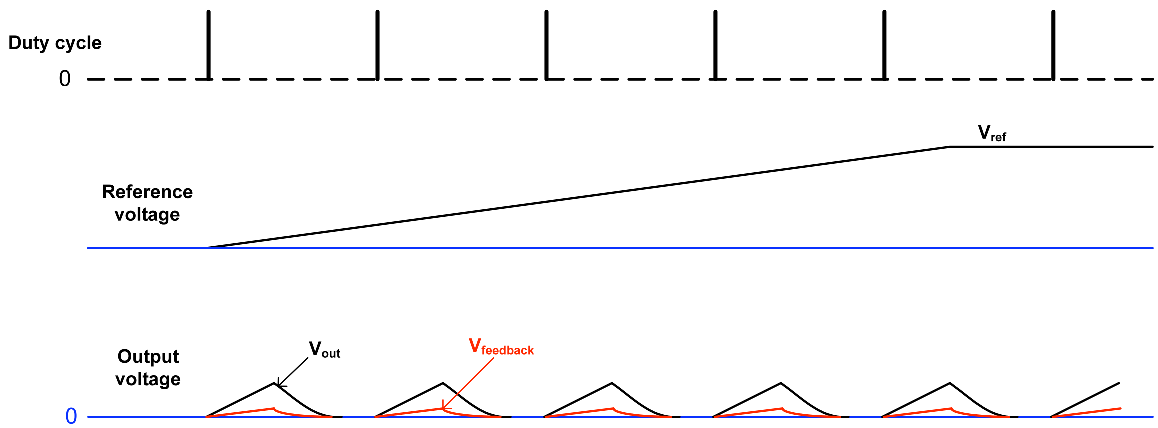

Figure 2: Soft start failure

3. The Correct Electronic Load Set Up

When testing start-up using electronics load, it is suggested to set the electronic load in CR mode. It is closest to the real application load condition and gives the best start-up waveforms.

If the start-up test has to be done with electronic load set in CC mode, several parameters need to be set up properly to guarantee successful start-up.

- Turn on voltage set to be at least 30% of regulation voltage. For example, the regulation output voltage is 5V, Von should be set higher than 1.5V. Never set up Von to 0V when test DC/DC converter or other DC power supply. It may cause unnecessary damage due to its turn on overshoot.

- Slew rate set to be approximately proportional to the output voltage slew rate. For example, the regulation output voltage is 5V, its soft start time is 5ms and full load is 5A, the slew rate should be set to 1A/ms. A higher slew rate can cause a dip on output voltage waveform which doesn't exist in real application condition.

- The load current should be reduced if the converter couldn't start up. For example, if converter couldn't start up when the electronic load is set to full load in CC mode, reduce load level to 50% of load to avoid triggering the short circuit protection.

- The Von latch switch should be off. It only allows the load to pull current when the load voltage is higher than the electronics load turn on.

4. Conclusion

The start-up test failure under constant current mode exists in some current-mode controlled buck regulators. Real applications rarely present a constant current behavior during start-up – sinking constant current even without voltage applied. For those ICs **without soft start**, it may be possible to start up because some electronics loads have a delay time due to its feedback design, when the load kicks in, the converter output voltage has already reached its regulation voltage. Soft start, however, is a very important feature for real applications because it can eliminate the inrush current; control the power up sequence and etc.

Appendix

Soft-start of AOZ101x

A soft start up process is illustrated by Figure 3 below. At the beginning of a soft start process, reference voltage starts to ramp up from 0V to 0.8V, feedback voltage follows the reference voltage and ramps up. From time t0 to t1, the feedback voltage is less than 0.2V, the short circuit protection circuit takes control and the PWM controller operates in short circuit protection mode. The converter switching frequency is only 1/8 of normal switching frequency, 500kHz. The average output current level ramps up slowly and charges the output capacitors.

When feedback voltage is above 0.2V at time t1, short circuit protection circuit releases and the PWM controller operates in normal mode. The switching frequency jumps from 1/8 of normal frequency to normal frequency, 500kHz. A tiny voltage glitch could happen due to this switching frequency transition. As the duty cycle opens wider and wider, the output voltage ramps up linearly to follow the internal reference voltage.

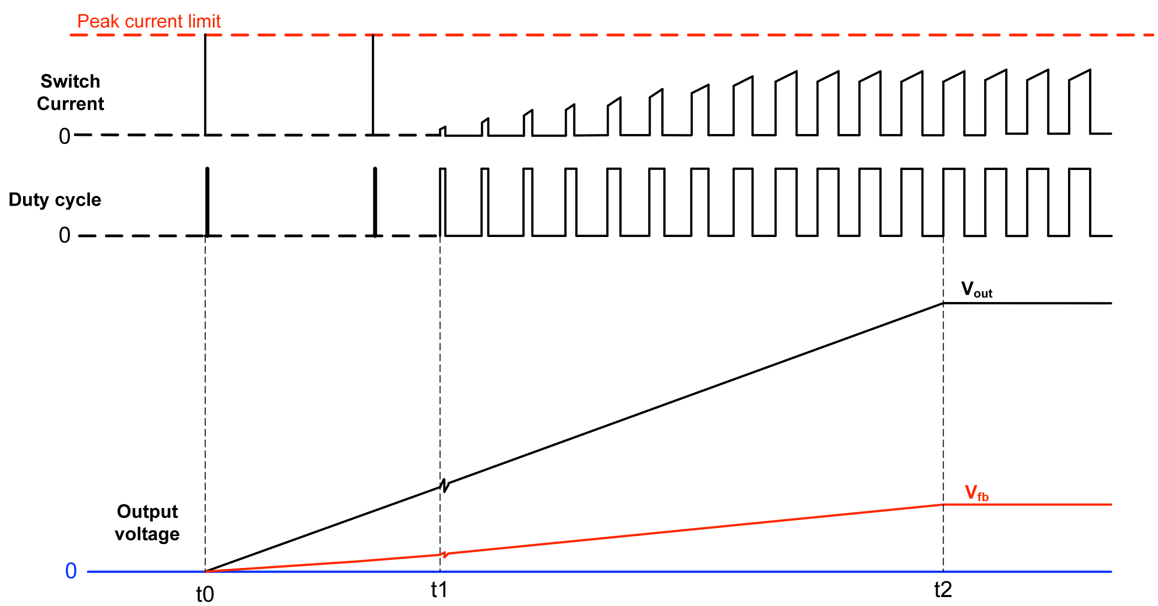

Figure 3: Soft start wave forms

At time t2, the output voltage reaches its set point and the soft start process ends.