INTRODUCTION

The TC170 is a CMOS current-mode PWM control IC. It features pulse-by-pulse current limiting, inherent feed forward, simple loop compensation, low power consumption, and an output stage optimized to drive power MOSFETs.

CURRENT-MODE CONTROL

Current-mode control has been an industry buzz word for some time but is still not well understood. Current-mode control is most often used for buck regulators and buck derivatives. It can be used for half-bridge designs, but is harder to implement.

There are a number of current-mode control schemes in use. The TC170’s architecture is that of a fixed frequency, peak current terminating design. The clock starts the cycle and when the peak current reaches a value set by \( V_{\text{REF}} \), the cycle is terminated until the next clock pulse (See Figure 2).

This then would be a system that appears as a constant current source. This current (in the primary of the transformer) is, in effect, very close to the value of the average current in the output inductor.

The output inductor is then effectively taken out of the feedback loop that we have added in Figure 3, because the inductor is fed from a constant current source. Since the inductor is effectively removed from the circuit, we don’t have to worry about the inductor resonating with the output capacitor causing an unstable or conditionally stable power supply. This makes the loop look like a single-pole system. This means that the loop gain decreases as the frequency increases at a rate of \( \approx 6 \text{dB per octave} \).

If the system did not have single-pole response (voltage mode control has double-pole response), the roll-off would be at 12dB per decade after the gain peak, due to the LC combination (see Figure 4).
So, one of the most, if not the most, significant points of current-mode control is that it makes it easier for the designer to close the control loop and make it stable.

**Oscillator**

One area in which the low power consumption of the TC170 is most noticeable to the user is in the oscillator section. The value of timing capacitors and resistors is much higher than its bipolar counterparts.

The dead time is a function of the value of the timing capacitor and reset current in the TC170. Typical values are 220pF to 3300pF. The formula in this datasheet is approximate and is typically within 25% to 33% of the actual value for any particular part.

Another way to calculate dead time is \( \frac{dv}{dt} = \frac{I}{C} \), where \( dv \) is the hysteresis of the comparator in the oscillator (≈2V), \( dt \) is the dead time, \( I \) is the reset current sink (≈1mA), and \( C \) is the value of the timing capacitor in farads. This method of calculation is most useful when the value of the timing resistor, \( R_O \), is 20kΩ and above.

The ramp-up time of the capacitor, which is the maximum pulse width, is set by the timing resistor on pin 9. Typical values are 5kΩ to 70kΩ.

The ramp never quite gets to 0V during reset; however, the higher the frequency of oscillation, the closer to 0V the bottom of the ramp gets.

**Voltage Reference and Undervoltage Lockout**

The voltage reference is set for 5.1V. This voltage is derived from a temperature-compensated zener diode with a buffered output. It can be used for a reference for the error amplifier and the current limit set point of pin 1.

The undervoltage circuit is specified for start-up point and hysteresis to the stop point. This allows the designer to accurately calculate when the TC170 will start and stop when powered by an external supply. Since this external supply may be the power line, this can be a very useful feature and can save costly external circuits that monitor the supply.

**Current-Limit Amplifier**

The current-limit amplifier is a fixed-gain, high-frequency amplifier. Its purpose is to allow a small input signal from a current-sense transducer, such as a current transformer or a resistor. By arranging for a small input, the losses across the current-sense element are held to a minimum.

The fixed gain of the current amplifier limits the input voltage to 1.1V. At this input voltage the amplifier has run out of swing and is approaching saturation.

The TC170 datasheet shows some typical current-sensing schemes.
Maximum Current Set Point (Pin 1)

The maximum current set point is adjusted by the value of the voltage that appears at pin 1. The TC170 datasheet shows how to set the value of the resistors for the intended application. These resistors also determine (by the amount of current flowing through the top resistor) the mode that the TC170 will go into upon shutdown. There are two modes, "hick-up" and latch (see Figure 5).

Shutdown

Hick-up mode is when the power supply resets itself upon shut-down and then goes through a soft-start cycle. If shutdown is still invoked, the power supply resets again and the cycle starts over.

The latch mode is set by allowing the current into pin 1 to be greater than 125µA. When pin 16 (the shutdown input) goes high, the shutdown comparator trips, causing Q2 to turn on, which generates a voltage feedback signal to the lockup amplifier. This turns on Q2, resulting in Q2 remaining on, no matter what the state of pin 16.

The only way out of latch mode is to stop current to pin 1. This is accomplished by recycling power to the TC170 or by opening the current path to pin 16.

The TC170 data sheet explains how to calculate the value of the divider string for the two modes and how to set the peak current limit.

By adding a capacitor from the intersection of R1 and R2 to ground, a soft-start function can be generated. The capacitor slowly charges, causing the voltage at pin 1 (which is the value of the peak current limit) to rise, and the pulse width to slowly increase. Note that, since the capacitor is fed from a voltage source, the rise is exponential, not linear.

Output Stage

The most important thing to remember about the output stage is that it is not possible to tie the output stage supply (pin 13) to a voltage more than ±350mV different than V IN (pin 15). This results in latch-up of the TC170. This latch-up phenomena is explained in Application Note 31.

FIGURE 5: Shutdown and current-limit control section, TC170.
Each output can drive a 1000pF load 16V in only 50nsec. If greater speed is required, an additional output driver, such as the TC44XX family, can be used in increase the output current. These drivers are capable of up to 6 amps of drive current.

Figure 5 shows how an external driver can help get around the limitation of only one power supply for the TC170.

CONCLUSION

The TC170 dissipates very little power when compared to its bipolar counterparts. This, combined with its fast rail-to-rail drive capability, makes the TC170 a natural replacement for bipolar parts.

**FIGURE 6:** Self-powered drive scheme.
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