AN2118

RediSem CV LED Driver Troubleshooting

Overview

This Quick Start Guide is a companion document to AN2117, the CV LED Design Guide and is intended to help you with troubleshooting your prototype LED driver. It assumes that your prototype is based on a standard RediSem Driver Application using the RED2541 LED CV control IC and uses the same component references for quick and easy reference.

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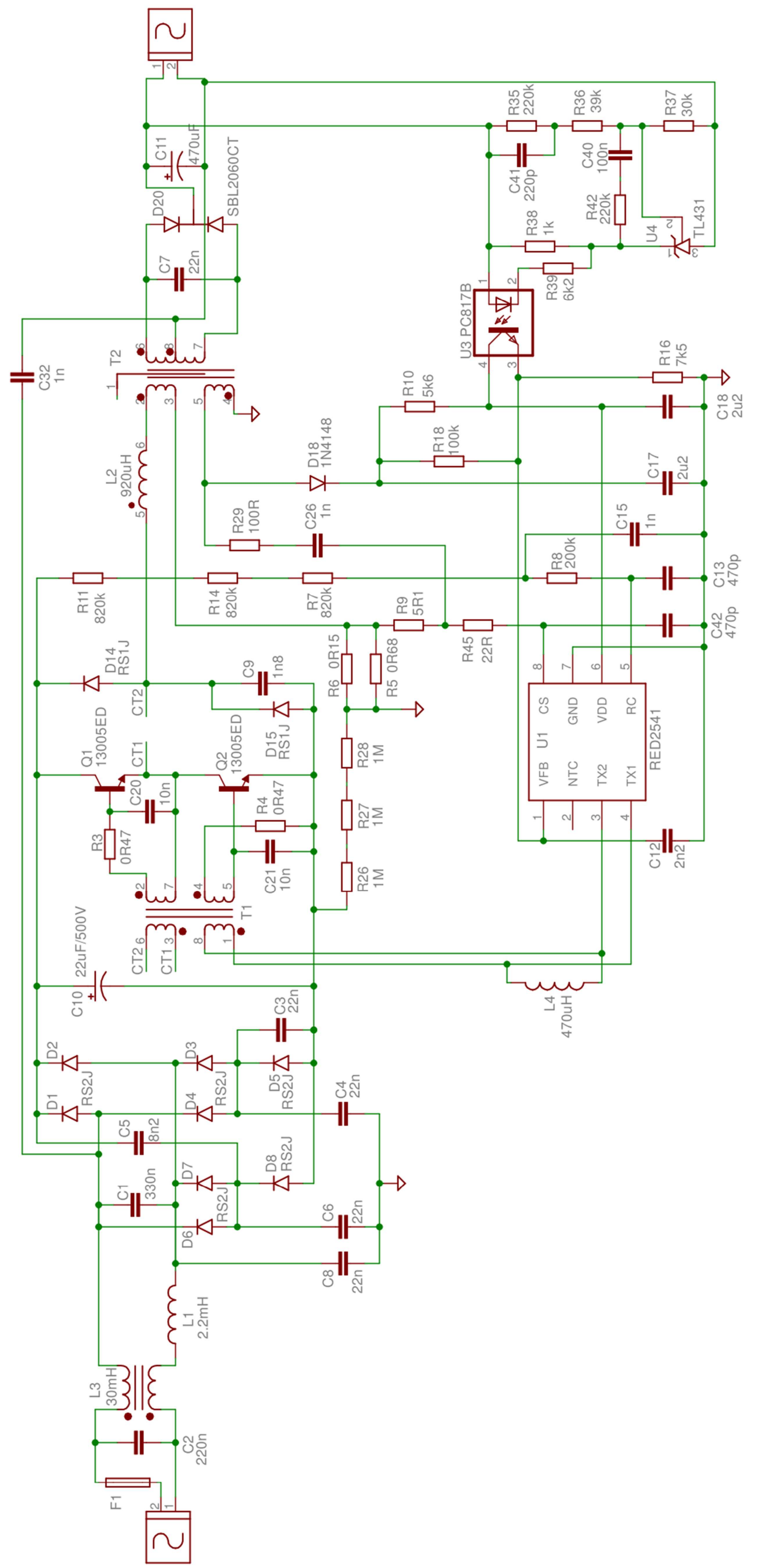

Figure *1*: Schematic of 60W CV LED Driver with PPFC, using RED2541

Troubleshooting Steps

Important Note: when attaching probes to the board under test, use a large common-mode choke in the line input to avoid getting misleading results and waveforms, and even damaging the circuit under test. It is best to use COM (pin 7 of the controller IC) as the scope ground reference point.

Start-up Problems

VDD rail stuck low

Check the VDD pin for a sawtooth waveform (Figure 2) – this shows that the IC (RED2541) is attempting to start up. If the VDD rail is stuck below 3.3V and there is no sawtooth, check:

- D_{18} damaged or wrong way round
- R_{18} or R_{19} value too low (remove them temporarily)
- R_7, R_8, R_{11}, R_{14}, R_{26}, R_{27}, R_{28} values too high
- C_{13}, C_{15} or C_{17} leaky
- U_3 (optocoupler) damaged
- RED2541 inserted the correct way around

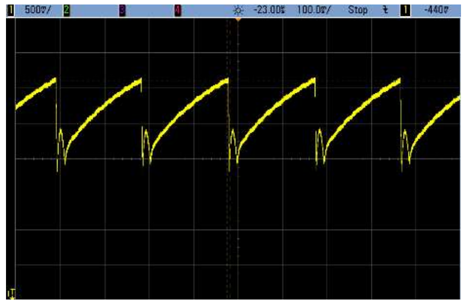

Figure 2: VDD (repeated re-start attempts)

No drive pulses

If the VDD sawtooth looks OK, next check TX1, TX2 pins on IC (RED2541) for drive pulses (Figure 3). If no pulses present, check:

- R_{15}, R_{41} open-circuit
- RED2541 pin 2 (NTC input) shorted to GND
- L_4 too small (remove temporarily)

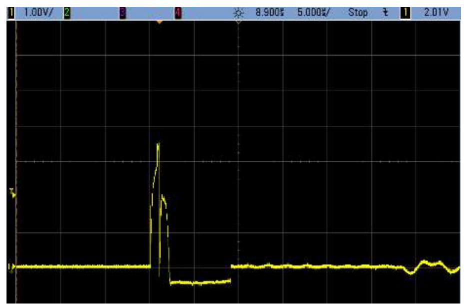

Figure 3: Tx pin drive pulse

BJTs not commutating

If there are drive pulses on TX1, TX2, check the Mid-Point node (junction of Q_1 emitter and Q_2 collector) for commutation (use HT- as the scope reference point). See Figure 4. If no commutation, possible faults include:

- T_1 windings incorrect
- R_3, R_4 damaged
- Q_1, Q_2 damaged
- RED2541 pin 8 (CS input) open-circuit
- C_9, C_7 too big
- Open-circuit fault in primary current loop

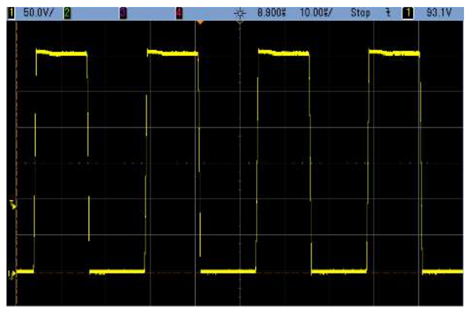

Figure 4: mid-point commutation

No output

If the BJTs are commutating, check the output terminals for sign of short-circuit fault (disconnect line and load terminals first). A short-circuit can be caused by a faulty output diode (D_{20}) or reversed output capacitor C_{11}. If no short-circuit is found, check:

- T_2 secondary windings phasing
- D_{20} output diodes

Turns on, but turns off after 1-5ms

Foldback Protection

The RED2541 includes a foldback protection to abandon startup if an abnormal load condition is detected. In foldback, the current limit is set to 50% until the output voltage reaches 30%. It is best to configure the E-load in constant resistance (CR) mode. However, if you have to test with an E-load in Constant Current (CC) mode, you must configure it to be inactive while the output voltage is below 30%.

Normal loads must comply with the characteristics shown in Figure 5. Suitable loads include the following:

- LED, CR (constant resistance) and CV (constant voltage);
- CC (constant current) and CP (constant power) – load must be inactive when V_{LOAD} < 30% V_{NOM}.

[Special note for CP loads and high capacitance loads: if the load requires a large current to pull it up, increase the value of R45 (maximum permitted value is 130Ω) but beware of higher peak currents in the primary loop causing problems – inductor saturation, etc]

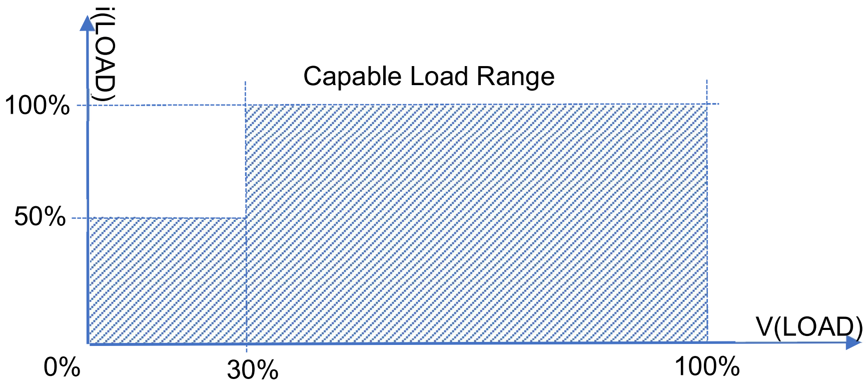

Figure 5: Static characteristics of allowed loads

VDD Supply drops out

Check VDD and primary current during start up (Figure 6). If VDD drops below 2.4V during the start-up, the IC will stop and re-start. Possible causes are:

C_{18} too small
C_{11} (or load capacitance) too large
Current Limit too low
T_2 aux winding too few turns
R_{10} value too large
D_{18} faulty/missing
R_{18} value incorrect
Secondary regulation error
R_{16}, R_{41} missing
C_{12} s/c fault

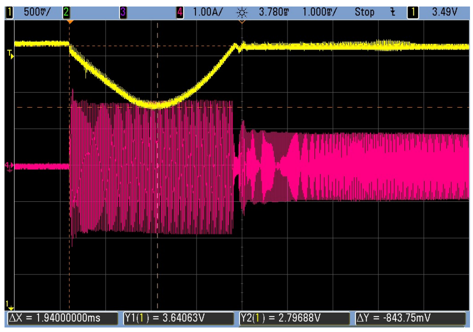

Figure 6: VDD, primary current (good startup)

If the load requires a large current to pull it up, increase the value of R45 (maximum permitted value is 130Ω) but beware of higher peak currents in the primary loop causing problems – inductor saturation etc.

VFB Low Fault

If VDD looks OK during startup, check RED2541 pin 1 (VFB input) during startup (Figure 7). If the VFB pin voltage has not risen above 300mV after 128 cycles (about 3ms), the controller registers a fault, shuts down and attempts to re-start. If this occurs, check:

- R_{18} missing or incorrect size
- R_{41} missing
- T_2 aux winding too few turns

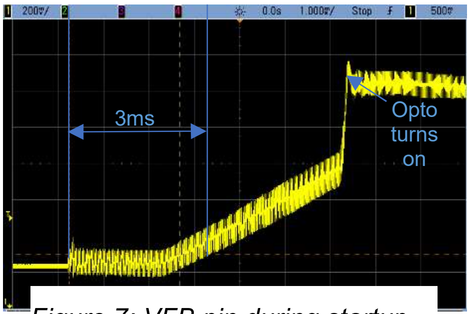

Figure 7: VFB pin during startup

Full load Regulation Problems

If the converter cannot maintain the output at full load, reduce the load until it can regulate, then perform the following checks:

Oscillator error

Monitor RED2541 pin 5 (RC input) waveform (Figure 8) through a line cycle. Check that the highest waveform peaks are less than 2.2V at full load. If not, check:

- C_{42} value
- R_7, R_8, R_{11}, R_{14} values

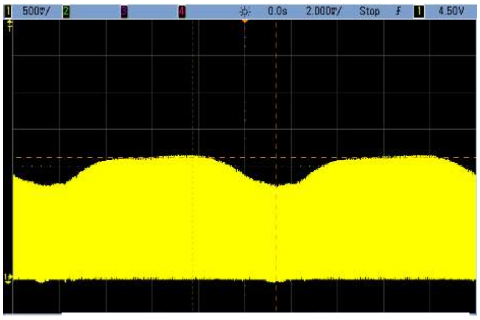

Figure 8: RC pin at full load

Current sensing error

Check:

- Value of R_5, R_6 (current sense resistors)
- Values of C_7, C_{26}, R_9 (parallel current compensation)
- Phase of Aux winding on T2 – change the direction if in doubt

Base Drive error

If the inductance seen across the control winding of T1 is too small, this will limit the frequency range, reducing the maximum output power.

Check:

- T_1, L_4 inductance values (remove L4 briefly to check)
- T_1 turns ratio

Capacitive mode protection error

Monitor the waveforms of primary current and RED2541 pin 5 (RC), checking for capacitive mode limiting. A good design should hit the capacitive limit at full load when line input is <198Vac. (Figure 10, Figure 9).

If capacitive mode limiting occurs within the target line/load range, check:

T_2 transformer turns ratio
R_5 value
Boost capacitor values

Figure 10: Primary current and RC pin on edge of capacitive mode switching

Figure 9: Primary current and RC pin on edge of capacitive mode switching (zoomed in)

Secondary voltage regulation error

If the output appears to be regulating too low, temporarily short out U_3 pins 1,2 (optocoupler inputs). If the output rises, it shows the problem is in the secondary voltage sensing circuit. Check:

R_{35}, R_{36}, R_{37} values
R_{38} value too high

High Output Ripple

Check the feedback loop values are all correct or similar to the suggested values. Check that there are no primary side regulation errors by increasing the value of R18. High leakage in the transformer can cause high spikes on the aux winding of T2. This is especially worse on low voltage high current designs

Primary voltage limiting error

Run the driver with nominal line, full load and temporarily short out the optocoupler LED (U_3 pins 1,2). The output voltage should rise to 105-110% of the nominal output voltage. If not, adjust the value of R_{18} (decrease R18 to decrease output voltage). Other things to check:

Noise on VFB pin (because C_{12} missing or too small)
T_2 – aux winding - too many turns?
T_2 leakage inductance – aux winding should be outermost (ie on top of the secondary windings)

Instability

Unstable at normal loads

Check primary current waveform for signs of instability across full range of line inputs, and load range 10%-100%. If system is unstable at nominal line voltage check:

C_{40} (increase value for more stability)
C_{11}, R_{35} (time constant should be ~50usec)
C_{12}, R_{41} (time constant should be ~20usec)
R_{39} (increase value for more stability)
R_{42} (too large?)
U_3 (optocoupler) gain factor

The values given in the reference design assume a typical low-cost optocoupler (e.g. PC817 grade B), with CTR < 260%. If the maximum CTR > 260%, consider increasing R39 value for stability. Decrease R39 for higher loop gain, lower output ripple.

If system is unstable only at low line voltage, check:

- T_2 turns ratio
- T_1 turns ratio
- T_1, L_4 inductance values (remove L_4 briefly to check)

Unstable at low loads

Burst threshold may be too high, refer to "Burst threshold problems" section below.

Unstable in standby

Check output voltage waveform for signs of instability in standby by stepping load from 10% and 0%. Some overshoot and undershoot is acceptable, see Figure 11. But, if instability is present, check:

- C_{40} value (too small?)
- C_{17} value (too small?)
- R_{10} value (too large?)
- R_{38} value (too large?)

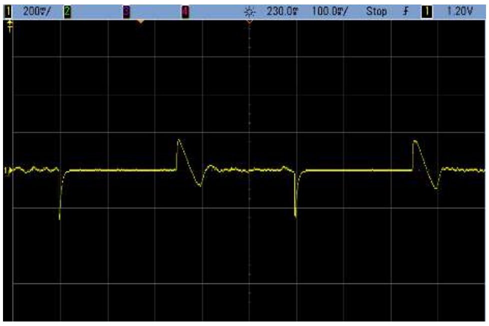

Figure 11: output voltage with load steps 0-10%

Burst threshold problems

The burst threshold should normally be in the load range 5-10%.

Burst threshold too high

If bursting occurs with loads > 10%, increase the load until it does run continuously then perform the following checks.

Oscillator error

Monitor RED2541 pin 5 (RC) waveform (Figure 12) through a line cycle. The controller IC will enter burst mode if the maximum frequency limit is reached, i.e. when the peaks of the RC waveform are <350mV.

Check that the lowest waveform peaks are >400mV. If not, check (decrease):

- C_{42} value
- R_7, R_8, R_{11}, R_{14} values

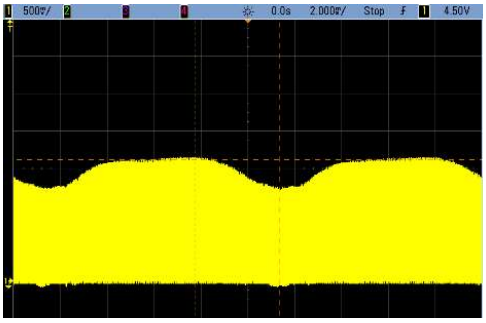

Figure 12: RC pin at 10% load

Load current correction error

Connect a scope probe (as close as possible) to RED2541 pin 8 (CS) and compare the waveform to the yellow trace in Figure 13 (some ringing is acceptable). If the flat parts of the waveform are very different to those shown, check:

R_9, R_{29} values
C_7, C_{26} values
T_2 construction - aux winding reversed or incorrect turns?

Figure 13: Primary current and CS pin waveforms

If the ringing is severe, check:

T_2 construction details – aux winding should be on outside of secondary windings
T_2 construction details – secondary windings leadouts must be short

Burst threshold too low

In no-load condition, if the driver does not enter burst mode, there is a problem with the load current correction - see section above.

Hot Transistors

Conduction Losses

Using a voltage-clamped scope probe amplifier (or equivalent) measure the on-state voltage. Check that the on-state voltage of both transistors is <300mV. If the on-state is higher than this, possible causes include:

Q_1, Q_2 current rating or h_{FE} too small
Base drive transformer T_1 turns ratio too large

Switching Losses

Check the storage and fall times of both transistors using scope probes to monitor the base-emitter and collector-emitter waveforms. At minimum line voltage and maximum load, the storage time (t_S) should be roughly 200ns and the fall time (t_F) should be <200ns. If this is not the case, possible causes include:

Q_1, Q_2 too slow
R_3, R_4 values too small
T_1 inductance too high
C_9 too small

Shoot-through

Monitor the collector current of Q_1 (or Q_2) using a current transformer. If there are any sharp current spikes in the waveform, please check:

Base Drive transformer T_1 construction – windings bunched incorrectly
Flywheel diodes D_{14}, D_{15} turn-on too slow
C_9 wrong side of T_1 primary winding

The ceramic capacitors C_{20}, C_{21} between base and emitter of Q_1 and Q_2 help to suppress shoot-through.

EMI

Conducted Emissions

50k – 500kHz

Differential-mode:
Increase C_1, C_2 and L_1 (Note: increasing C_1, C_2 will reduce PF)

Common-mode:
Make sure that the transformer construction (order and phasing of windings) is correct. A screen winding should not be necessary, but can help if all else fails.
Minimise lengths of secondary winding leadouts.
Increase common-mode choke L_3 or the Y-Capacitor C_{32}.
Check PCB tracking. Make sure that the noisy midpoint node is not close to the secondary or mains input.

2MHz – 30MHz

Minimise lengths of PCB tracks associated with base drive transformer T_1.

Radiated Emissions

30 - 100MHz

Minimise the tracking around the T_1 base drive transformer.
Test to see if one of the diodes D_{14}, D_{15} is causing ringing.
Add 10R in series with aux diode D_{18}.
Divide the midpoint capacitor C_9 into two and place directly across the freewheel diodes D_{14} and D_{15}

Harmonics Emissions

Non-compliant at low line, high load

Boost voltage too high

C_3, C_5 values too small
C_4, C_6, C_8 values too large

Non-compliant at high line, low load

Boost voltage too low

C_3, C_5 values too large
C_1, C_4, C_6, C_8 values too small

Power Factor

As for Harmonics Emissions above, plus:
C_1, C_2 values too large – Increase the size of the Inductor to maintain EMI compliance

Fault Protection

Short-circuit load – Bulk Supply Voltage too high (PPFC apps only)

T_2 aux winding turns ratio
T_2 construction – Aux winding should be outside the secondary windings

Optocoupler fault - output voltage too high

R_{18} too large
Voltage control loop unstable (see above)
C_9 too large

T_1 or L_4 inductance too large

Capacitive Mode happens at normal line voltages

T_2 turns ratio too low
C_9 value too large

Fault Recovery Time

Too short:

Increase C_{17}, C_{18}
Increase R_7, R_{11}, R_{14}
(adjust C_{13} to keep same clock setting)
(adjust R_{19} to keep same minimum line voltage for startup)

Too long:

Decrease C_{17}, C_{18}
Decrease R_7, R_{11}, R_{14}
(adjust C_{13} to keep same clock setting)
(adjust R_{19} to keep same minimum line voltage for startup)

About RediSem

RediSem designs and supplies semiconductor ICs for energy efficient power management applications. RediSem uniquely combines extensive experience in power electronics with in-depth knowledge of IC design and manufacturing and works with the world's top suppliers and customers. RediSem's unique patented IC and converter technologies deliver maximum efficiency and performance, while reducing overall bill of materials cost through the use of bipolar transistors.

RediSem's range of LED control ICs can be used with RediSem's patented single stage LED control solution to provide very high efficiencies with low EMI – all with a single IC. When combined, these features deliver a low cost, high performance LED driver solution.

RediSem's fluorescent driver controller ICs achieve the advanced performance of MOSFET drivers by using bipolar transistors at a fraction of the BOM cost. RediSem's range of SMPS (Switched Mode Power Supply) control ICs enables low-cost LLC converters with bipolar transistors that deliver very high efficiencies already meeting DoE Level VI regulations, have low standby power and have much lower EMI compared to flyback converters.

All RediSem ICs are supported by comprehensive turn-key application designs enabling rapid time to market. For further information please use our contact details below

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