Pick the right turns ratio for a Fly-Buck™ converter

While the Fly-Buck™ is a convenient option for a simple isolated bias voltage, one must still be cautious when considering running at high duty ratios.

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Sometimes you are faced with a need for a simple, low-power isolated output voltage from a wide-ranging input source. Regulation may not be important, but cost and board area may be. A good solution to these requirements is a Fly-Buck power supply, which is simply a buck regulator with a coupled-winding.

Regulation is achieved by rectifying the secondary winding of the coupled inductor, when the low-side primary switch is on. This reflects a voltage to the secondary that is set by the output voltage of the buck times the turns-ratio of the coupled inductor.

For an overview of the circuit operation, see **"Design a simple, isolated bias supply"**.

Figure 1 shows how simple a Fly-Buck can be. In this design, the sync-buck power switches are contained within the control IC and it only takes a handful of discrete parts plus a transformer to complete the design. The real trick for a successful design is the specification or selection of the coupled inductor. In particular, requirements for turns, leakage inductance, and magnetizing inductance need to be established.

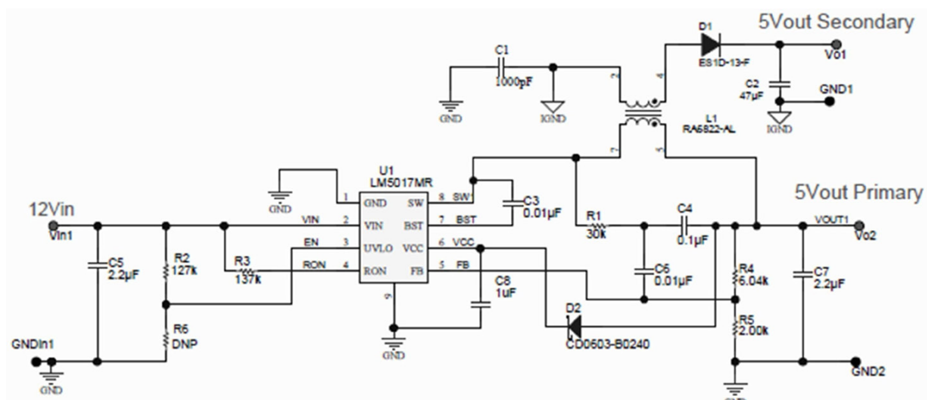

Figure 1: The Fly-Buck is a simple way to provide a regulated, isolated output.

In the circuit shown in ***Figure 1***, the turns-ratio of the transformer is established by the primary and secondary output voltages. It will simply be the ratio of the primary voltage to the secondary voltage plus allowances for the diode (D1) voltage and any winding resistance drops. In this case, the relationship between the primary output voltage and the minimum input voltage needs to be understood. Clearly, the buck cannot provide an output higher than the input. If the two are too close together, the circuit may not function properly. You may be limited by the maximum duty cycle of the control since the output voltage is approximately the duty factor times the input.

The second challenge is in the circuit operation at extremely high duty factors, where the currents can be become quite high. These high currents can result from both charge conservation and the basic circuit operation.

From charge conservation, the output capacitor is only charged when the switch node is low. During the remainder of the period, it sources the load current. On an average basis, to conserve charge:

$$Iout * (D) = Icharge * (1 - D)$$

$$D = \frac{Vout}{Vin}$$

$$Icharge = Iout * \left(\frac{D}{1 - D}\right) = Iout * Vout/(Vin - Vout)$$

Selecting turns for DC/DC ratio converter

This result is plotted in ***Figure 2*** where Icharge/Iout is plotted versus D. At duty factors above 75%, the ratio is above three and climbs quite rapidly with increasing duty factor. The high current impacts regulation of the secondary output. During diode conduction, the coupled inductor places a reflected primary output voltage across the series combination of the coupled inductor leakage inductance, series parasitic resistances and the output filter capacitor.

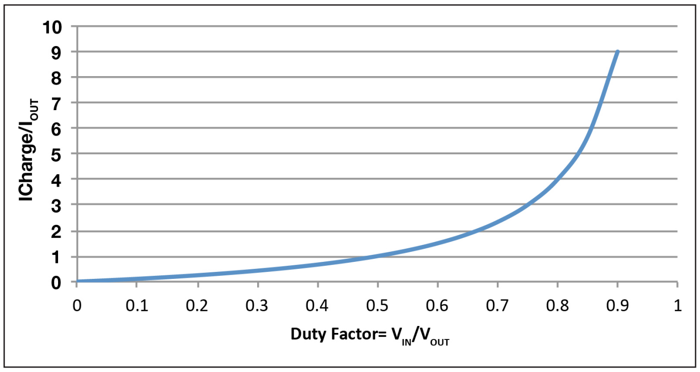

Figure 2. Capactior C7 charge current is high for high duty factor or Vo near Vin.

The current waveform in the secondary shown in the bottom traces of ***Figure 3*** are strongly influenced by the leakage inductance which will impact regulation. The leakage inductance determines how quickly the current in the secondary winding can ramp. With small amounts of leakage inductance, the currents ramp quickly to a high value which charges the output capacitor quickly. As the inductance is increased, the current rise is slowed which can result is less charge being supplied to the output capacitance and less output voltage.

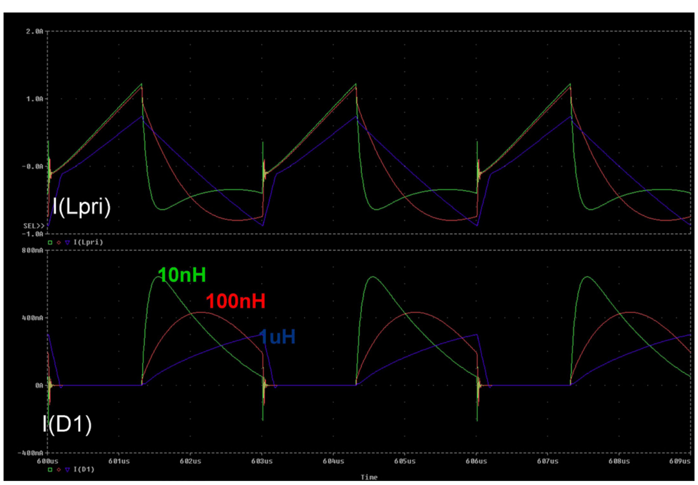

Figure 3. Recharge current wave shape is strongly impacted by leakage inductance. (Green = 10 nH, Red = 100 nH, Blue = 1 µH)

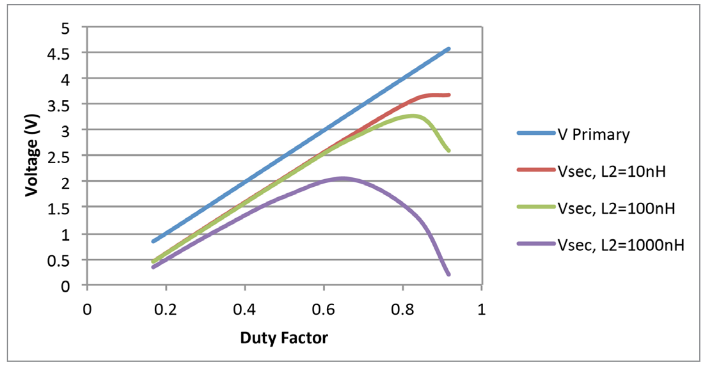

Figure 4. Leakage inductance is a killer on regulation.

Figure 4 shows the simulated impact of the leakage inductance on the secondary output regulation. This chart plots primary output voltage and secondary output voltage as a function of duty factor and leakage inductance. This was based on a 1:1 transformer with a 2.5 µH primary inductance and varying amounts of leakage. The input voltage was 5 V. The primary was loaded with 1 A of current and the secondary was loaded with 0.2 A.

The first curve is the primary output voltage, which shows a linear relationship between duty factor and output voltage. The remainder shows that there is not a linear relationship for the secondary output voltage.

There are two things that are degrading the secondary regulation. On the left, at lower duty factors, the secondary output voltage is approximately one diode drop less than the primary voltage. This could be improved with synchronous rectification. On the right, at higher duty factors, the shorter conduction time increases the peak currents and the impact of the leakage inductance becomes significant.

With large amounts of leakage, the circuit is probably not usable beyond 50% duty factor or a ratio of 2:1 between input and output. With a nominal amount of leakage, the circuit performed well up to 75% or 1.33:1. Finally, with a heroic leakage inductance, the circuit is good to 83% duty factor or a voltage ratio of 1.2:1. It should be noted as shown in ***Figure 2***, the peak and RMS at high duty factors can be quite high. These are strongly influenced by parasitics and the easiest way to understand them is through simulation.
To summarize, the Fly-Buck is a convenient choice for a simple isolated bias voltage, but you need to be careful when considering running at high duty ratios. Peak currents can become quite high. Controlling leakage inductance allows you to push the duty factor, but anything much more than 80% is probably impractical.

Selecting turns for DC/DC ratio converter

Fly-Buck Transformer List

Vendor	Transformer Part Number	Lpri (µH)	Llk (µH)	Turns Ratio	PMP/TI Design #
Wurth-Midcom	750314442	45	0.93	1:0.48:0.48:0.96:0.96	PMP9478
Wurth-Midcom	750314461	45	0.35	1:0.52:0.52:1.56	PMP10558
Wurth-Midcom	750314459	45	1	1:0.56:0.56:0.72:0.72	PMP10543
Wurth-Midcom	750314460	45	0.91	1:0.56:0.56:1.28:1.28	PMP10535.3
Wurth-Midcom	750314462	45	0.45	1:0.56:1.24:1.24	PMP10558
Wurth-Midcom	750314624	60	0.4	1:0.93:0.93:1.62:1.62	TIDA00174
Wurth-Midcom	750314441	80	1.5	1:0.389:2.56	TIDA-00129
Coilcraft	LPD5030V-333ME	33	–	1:1	LM5017 EVM
Wurth-Midcom	750342304	260	8	1:1	TIDA-00018
Wurth-Midcom	750311880	2.5	0.125	1:1	TPS55010EVM
Wurth-Midcom	750312750	23	0.2	1:1	LM34927EVAL
Wurth-Midcom	750342156	66	1.5	1:1:1	TIDA-00123
Wurth-Midcom	750314463	45	0.45	1:1.16:1.16:2.36	PMP10558
Wurth-Midcom	750314226	33.8	0.15	1:2:2	PMP9317
Wurth-Midcom	750315038	36.5	0.3	1:2.33:2.33:2.33:2.33	TIDA-00199
Wurth-Midcom	750311780	2	0.08	1:8	TPS55010 Dual Output EVM
Wurth-Midcom	750314597	60	0.6	1.5:1	LM5160A Fly-Buck EVM
Premier Magnetics	TSD-3425	50	–	1.5:1	PMP7993
Premier Magnetics	TSD-3424	50	–	1.5:1:2	PMP7993
Wurth-Midcom	750342178	50	2	1.55:1.55:1.935:1.935:1	TIDA-00118 TIDA-00119 TIDA-00017
Wurth-Midcom	760390015	475	–	2:1	TIDA-00123
Premier Magnetics	TSD-3426	50	–	2:1	PMP7993
Wurth-Midcom	750314225	50	0.4	3:2:2	PMP9316
Wurth-Midcom	750313995	50	0.13	3:2:2:4:4	PMP7993
Wurth-Midcom	750315039	40	0.3	6:4:11:11	PMP10532

Read a companion article Product How-to: **Fly-Buck adds well-regulated isolated outputs to a buck without optocouplers** in EDN Magazine.

For additional Fly-Buck design resources, visit **ti.com/fly-buck**

For more information on using a Fly-Buck in high-power applications, visit **ti.com/widevinindustrial**

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