Gate Drive Method Extends the Power Supply Input Voltage Range

In industrial and telecom applications, there can be a need for a nonisolated low voltage supply from a high voltage input. IC manufacturers have responded to that need with the application of high voltage processes, and offer control ICs that work to 50 volts and above. Sometimes that is not enough, and further design techniques are required to extend the input voltage. One such technique is shown in the buck converter of Figure 1. In addition to enabling circuit operation over a very wide input voltage range, the technique reduces power dissipation, as the control circuit does not operate directly from Vin.

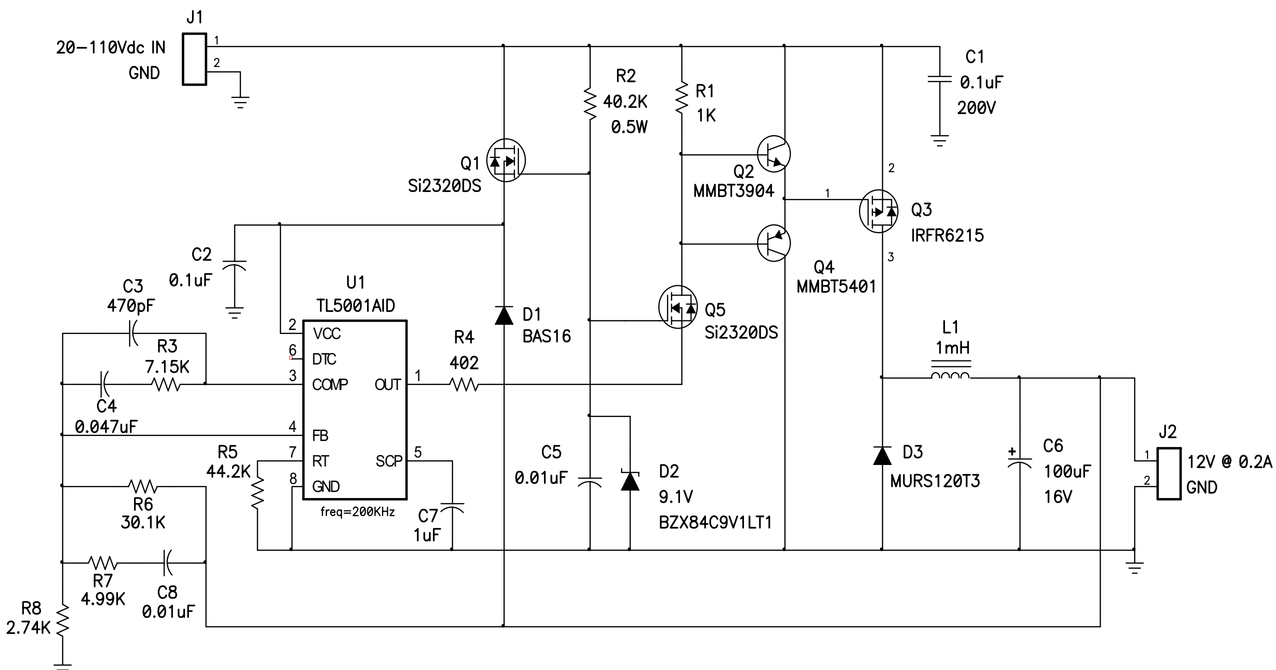

Figure 1. Buck Converter uses Switched Source Gate Drive

The circuit employs a linear regulator and a source-switched driver to buffer a control IC from a line that goes as high as 110 volts. When the input voltage is applied, current flows through resistor R2 and zener diode D2, clamping the gate voltage of FET Q1 to 9.1V. C2 will reach a voltage of approximately 6V, which is equal to the Q1 gate voltage minus its typical turn on threshold of 3V. FET Q1 acts as a crude linear regulator at this time, and allows the control circuit to become active. The source-switched driver of Q2, Q4, and Q5 then allows the supply to come into regulation. The TL5001 open collector output switches to a low state to turn on the main power switch Q3. With the gate of FET Q5 also held at 9.1V and the output pin of the TL5001 low, current will flow through the Q5 drain to the source pins. The amount of drain current that flows is equal to:

(9.1V – Q5 turn on threshold – U1 pin 1 saturation voltage) / R4

In this example, this current is nominally about 12mA. Since the majority of this current flows through R1, the value of R1 sets the voltage amplitude that is used for the gate drive of Q3. With a value of 1kΩ for R1, the voltage across it is 12V. Transistors Q2 and Q4 form an NPN/PNP pair used to switch gate drive current into and out of Q3. The base-emitter junction of Q4 conducts when there is a voltage dropped across R1. This pulls the gate of Q3 down, from Vin, to approximately 11.2V (12V – 0.8Vbe). Since Q3 is a P-channel FET, pulling the gate to 11.2V less than the source, turns it on. When current is not flowing in R1, the base of Q2 is pulled up to Vin, which forward biases its base-emitter junction. The gate of Q3 is charged to near Vin potential, turning it off. This drive circuit is fast as none of the transistors are operating in a saturated mode and 0.5 μsec Q3 on times can be obtained. This means high operating frequencies are achievable with the low duty cycles encountered in a high voltage input. This gate drive circuit can be scaled for higher or lower input voltages by the proper selection of the drain-source (or collector-emitter) ratings of Q1, Q3, Q4, and Q5. All must have voltage ratings selected to be greater than the input voltage and should also be capable of fast switching speeds, with the exception of Q1.

The addition of diode D1 offers two advantages:

1. It allows the control circuit to operate after startup from the output voltage, rather than the input voltage. This is a more efficient method, considering that the input voltage is high. A bias power savings of approximately 7X is realized in the application.
2. Also, adding D1 pulls the source pin of Q1 to approximately 11.2V, which turns it off. All bias power to the controller is now sourced from the output voltage. Q1 no longer dissipates power.

Table 1. PMP096 Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
1	C9	0.01μF	Capacitor, Ceramic, 0.01μF, 25V, X7R	603	GRM39X7R103K025A	Murata
1	C3	0.01μF	Capacitor, Ceramic, 0.01μF, 25V, X7R, 10%	603	GRM39X7R103K025A	Murata
1	C5	0.047μF	Capacitor, Ceramic, 0.047μF, 25V, X7R	603	GRM39X7R473K025A	Murata
1	C2	0.1μF	Capacitor, Ceramic, 0.1μF, 25V, X7R	603	GRM39X7R104K025A	Murata
1	C4	470pF	Capacitor, Ceramic, 470pF, 50V, X7R	603	GRM39X7R471K050A	Murata
1	C6	1μF	Capacitor, Ceramic, 1μF, 16V, X7R	805	GRM40X7R105K16PT	Murata
1	C10	0.01μF	Capacitor, Ceramic, 0.1μF, 200V	1812	GRM43-2X7R104K200	Murata
1	C11	100μF	Capacitor, Aluminum, 100-μF, 16-V	0.217 × 0.256	UUD0C101MCR1GS	Nichicon
1	D1	BAS16	Diode, Switching, 100-mA, 75-V, 350-mW	SOT23	BAS16	Vishay-Liteon
1	D5	9.1V	Diode, Zener, 9.1V, 350-mW	SOT23	BZX84C9V1LT1	Diodes, Inc.
1	D3	MURS120T3	Diode, UltraFast Rectifier, 1-A, 200-V	SMB	MURS120T3	On Semi
1	L2	1mH	Inductor, SMT, 1mH, 0.3-A, 3-Ω	0.51 × 0.37	DO3316P-105	Coilcraft
1	R1	1K	Resistor, Chip, 1kΩ, 1/16-W, 1%	603	Std	Std
1	R7	2.61K	Resistor, Chip, 2.61kΩ, 1/16-W, 1%	603	Std	Std
1	R6	4.99K	Resistor, Chip, 4.99kΩ, 1/16-W, 1%	603	Std	Std
1	R2	7.15K	Resistor, Chip, 7.15kΩ, 1/16-W, 1%	603	Std	Std
1	R5	30.1K	Resistor, Chip, 30.1kΩ, 1/16-W, 1%	603	Std	Std
1	R4	44.2K	Resistor, Chip, 44.2kΩ, 1/16-W, 1%	603	Std	Std
1	R3	402	Resistor, Chip, 402 Ω, 1/16-W, 1%	603	Std	Std
1	R21	40.2K	Resistor, Chip, 40.2kΩ, 1/2-W, 1%	1210	Std	Std
1	U1	TL5001AID	IC, Low-Cost PWM Controller w/Open-Collector Output	SO8	TL5001D	TI
2	Q3	Si232DS	MOSFET, N-ch, 200V, 7 Ω	SOT23	Si2320DS	Siliconix
	Q4	Si2320DS	MOSFET, N-ch, 200V, 7 Ω	SOT23	Si2320DS	Siliconix
1	Q1	MMBT3904	Bipolar, NPN, 40V, 200mA, zz-W	SOT23	MMBT3904	On Semi
1	Q2	IRFR6215	MOSFET, P-ch, –200V, 0.295 Ω	DPAK	IRFR6215	IR
1	Q6	MMBT5401	Bipolar, PNP, xx-V, yy-mA, zz-W	SOT23	MMBT5401	On Semi

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