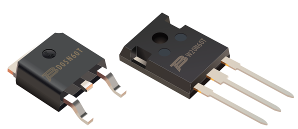
APPLICATION NOTE

Why IGBTs are Optimal Electronic Switching Solutions for Inductive Heating Applications



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INTRODUCTION

Many processes vital to industrial and cooking operations involve the generation of heat. The most efficient way to apply heat is to generate it at the point of application. In this way, basically all the heat generated goes directly to its intended operational use and not to the surrounding environment. Inductive heating that takes electrical power from the electrical mains and transforms it into an inductive heating coil is the ideal and most effective method to produce heat for these processes.

Concentrating heat in a given area is accomplished by producing electromagnetic fields in an induction coil and to the item to be heated. Whether to heat a steel rod in the manufacturing process or to warm a cast iron frying pan for cooking food (as shown in Figure 1), inductive heating produced with electricity is typically the most common approach. Induction heating works by inducing eddy currents in items that contain iron, such as steel and cast iron. The eddy currents create heat in the source directly, so it is the only article that gets hot.

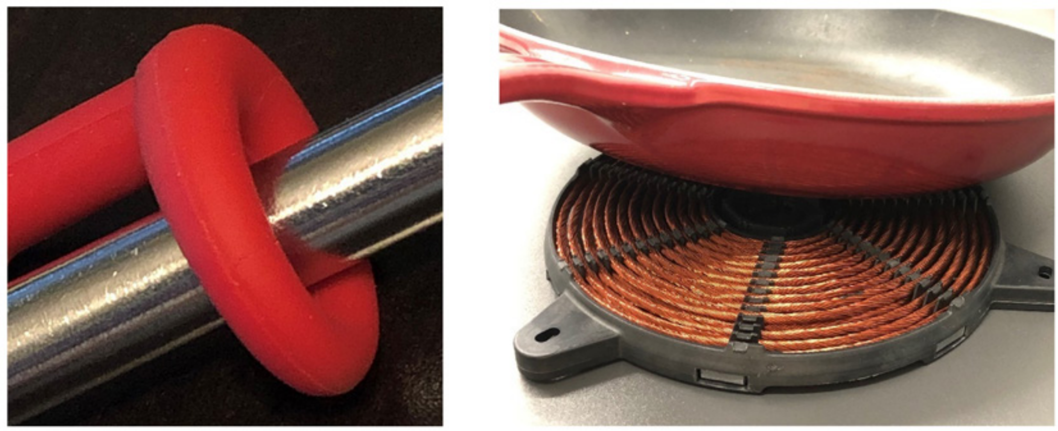
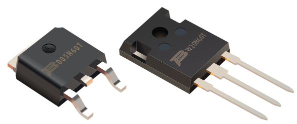


Figure 1. | *Examples of inductive heating for industrial and cooking processes*

To create the electromagnetic field in the induction coil requires high power electronic switches operating at a frequency from 20 kHz to 50 kHz. This application note will explain how high power electronic switching is supported and accomplished with MOSFETs or IGBTs (Insulated Gate Bipolar Transistors). It will also cover the effects on both the MOSFETs and IGBTs from conduction loss due to the high currents involved. The advantages of Bourns' line of discrete IGBTs for inductive heating will be shown, specifically describing the features that allow high frequency switching circuits to have lower losses compared to similar competitive devices.



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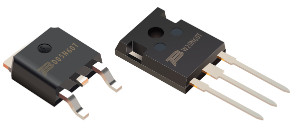
INCREASING EFFICIENCY WITH SWITCHES

The efficiency of a heating application is maximized by the peak current in an L_C resonant load when the frequency is set so the inductive reactance cancels the capacitive reactance, and employs zero voltage switching, also called soft switching. In soft switching, employing an IGBT with an integral Fast Recovery Diode (FRD) provides the benefit of behaving as a current steering mechanism rather than an absolute current switch. The current is switched only when the voltage is zero, thus avoiding the extra switching current loss. The remaining loss mechanism is the current conduction loss, which is minimized in IGBTs since the loss is the current flowing through the voltage drop from collector to emitter. The current conduction loss experienced is less than if a MOSFET was used where the current flows through the channel resistance of the device. Using soft switching with IGBTs also has the effect of minimizing the stress placed on the transistors so that higher power is attained with a simplified circuit and thermal design.

In addition, using a resonant load means that the inductance in the induction coil and the item to be heated is cancelled by the resonant capacitor. This leads to a reduction in voltage transients that reach the IGBT. With a resonant load there is very little kickback voltage due to the collapse of the magnetic field, as in the case of switching an inductive load. When operating at moderately high switching frequencies, IGBTs are known to keep the collector current flowing in short enough periods to avoid the danger of looking like a short circuit each half cycle. This also reduces the peak current and the power for which IGBTs must be rated.

Why IGBTs are Optimal Electronic Switching Solutions for Inductive Heating Applications



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COMPONENTS FOR HEAT GENERATION

The main components needed to generate this heat energy are IGBT switches, a resonant capacitor, an induction coil, and the item to be heated. A corresponding block diagram is shown in Figure 2. For low power induction heaters, one IGBT is sufficient. High power induction heaters typically used in industrial settings require four IGBTs arranged in a bridge circuit. See Figure 4.

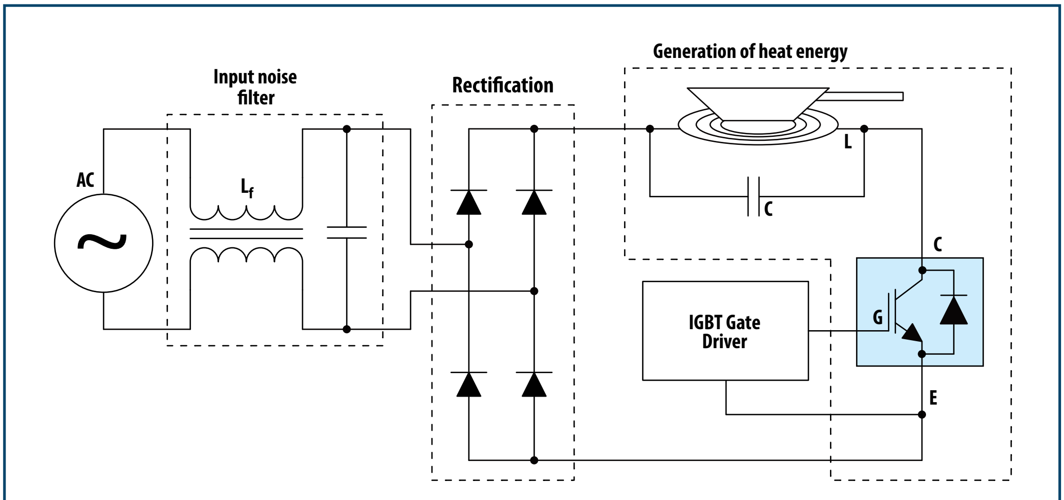


Figure 2. | *Basic induction heating circuit*

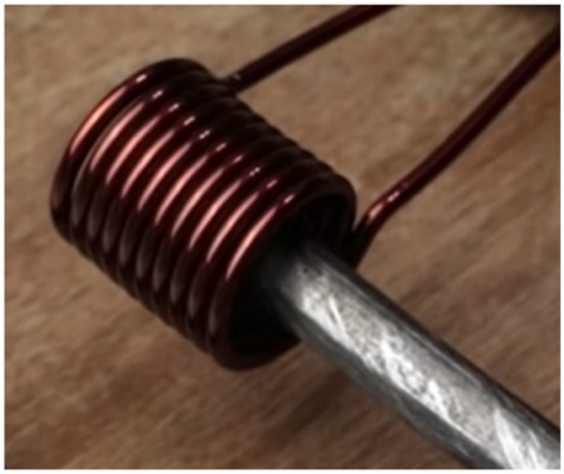
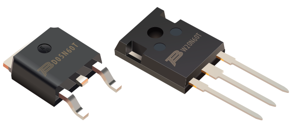


Figure 3. | *Industrial heating solenoidal application*

The induction coils can also take the shape of a multiturn solenoid for industrial heating applications, as shown in Figure 3. The current in the turns of wire concentrates the magnetic field in the item to be heated, which is passed through the center of the coil. The heated items need to be ferrous so they can be acted on by the magnetic field.



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COMPONENTS FOR HEAT GENERATION

A simple rectifier or power factor correcting circuit is used to obtain power from the AC mains, usually 240 VAC_{rms} single-phase or at a higher voltage and 3-phase for higher power applications. The DC voltage from the input rectifier provides power to the resonant converter to set up the high currents in the resonant loop. The resonance effect multiplies the current so large electromagnetic fields in the coil that are directed into the item to be heated create maximum heat without being in contact with it. The resonant coil and heated item are sometimes separated by a shield in addition to air that is transparent to the magnetic field.

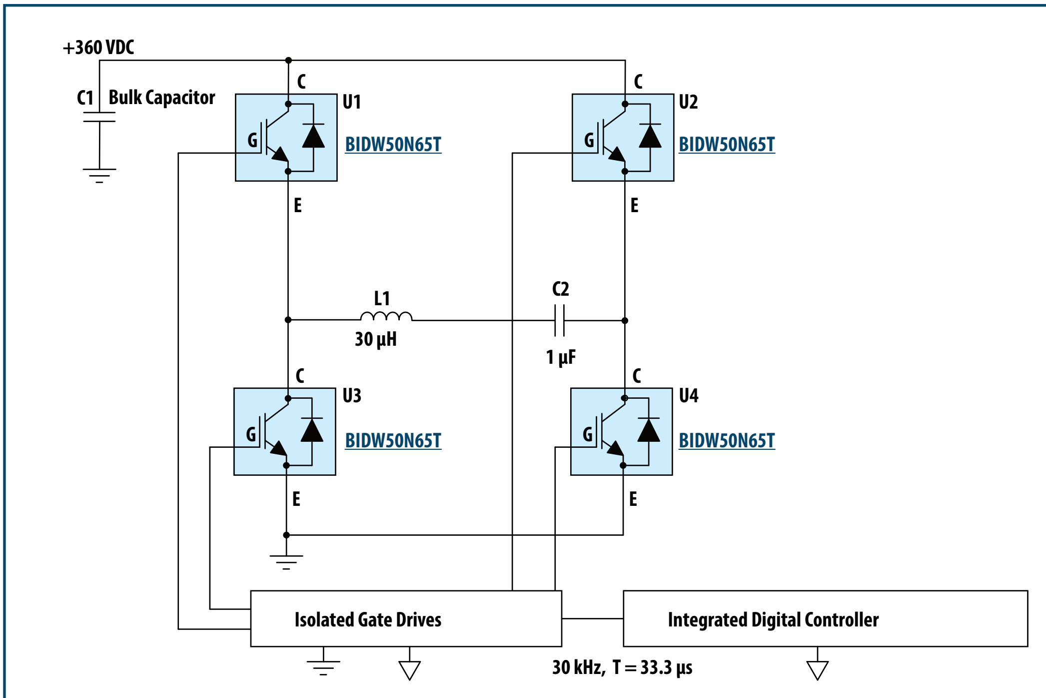
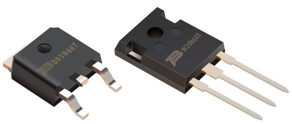


Figure 4. | *Inductive heating generator using Bourns® Model BIDW50N65T IGBTs in a bridge circuit*

In this circuit diagram, the IGBTs are arranged in a bridge with the gates driven so the induction coil L1 and resonating capacitor C2 are alternately connected to the DC supply voltage. To accomplish this, U1 and U4 are enabled. Then, on the next half-cycle of the 30 kHz driving waveform, U2 and U3 are enabled. The integrated digital controller and isolated gate drivers control the switching.



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COMPONENTS FOR HEAT GENERATION (Continued)

IGBTs have been shown to perform as highly efficient switches that enable heat sources to be small and lightweight. Bourns® IGBTs with enhanced thermal properties in the packages using lower thermal resistance meet the typical low profile, compact size and thermal management requirements in these designs. The available IGBTs are listed in Table 1 with their thermal performance specifications.

Table 1. Bourns® IGBT thermal performance parameters.

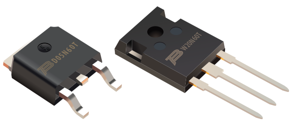
Bourns Part Number	$R_{th(j-c)}$_IGBT	$R_{th(j-c)}$_Diode	$P_{(tot)}$ @25 °C	Package
BIDD05N60T	1.51	2.14	82	TO-252
BIDW20N60T	0.65	1.19	192	TO-247
BIDNW30N60H3	0.54	1.5	230	TO-247N
BIDW30N60T	0.54	1.2	230	TO-247
BIDW50N65T	0.3	0.65	416	TO-247

Modern digital control circuits streamline the control and tuning of the gate controls in gate driving circuits so that the highest efficiency is achieved. Bourns' family of IGBTs allow the circuits to function with the extremely low amounts of high frequency noise. The lower noise level is enabled by the moderate switching speeds of the Bourns® IGBTs shown in Table 2. This helps to decrease the number of components required for EMI compliance which, in turn, helps reduce the design's total BOM cost.

Table 2. Bourns® IGBT switching performance parameters.

Bourns Part Number	$T_{delay(on)}$ Typ. @ T_c=25 °C (ns)	T_{rise} Typ. @ T_c=25 °C (ns)	$T_{delay(off)}$ Typ. @ T_c=25 °C (ns)	T_{fall} Typ. @ T_c=25 °C (ns)	$T_{rev-rec}$ Typ. @ T_c=25 °C (ns)
BIDD05N60T	7	14	18	145	40
BIDW20N60T	19	55	48	115	33.7
BIDNW30N60H3	30	105	67	100	28
BIDW30N60T	30	105	67	100	40
BIDW50N65T	37	133	125	121	37.5

The feature benefits of Bourns® IGBTs, combined with the ease of driving the gates in a similar manner as MOSFETs, makes designing a complete inductive heating application circuit a more straightforward and simple process.



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CONCLUSION

Using IGBTs in the resonant bridge configuration simplifies the implementation of the inductive heating application. This is advantageous for various heating applications, ranging from consumer and commercial cooking to industrial processes using ferrous materials.

For more information on Bourns' high-performance discrete IGBT product offering, check out our additional available resources through the links below.

ADDITIONAL RESOURCES

- Product Page: Bourns Discrete IGBTs
- Technical Library: Bourns Discrete IGBTs
- White Paper: Understanding IGBT Data Sheet Parameters
- White Paper: Achieving Fast IGBT Reverse Recovery Loss
- White Paper: Measuring IGBT Conduction Loss to Maximize Efficiency
- White Paper: Bourns® IGBT vs. MOSFET - Determining the Most Efficient Power Switching Solution

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