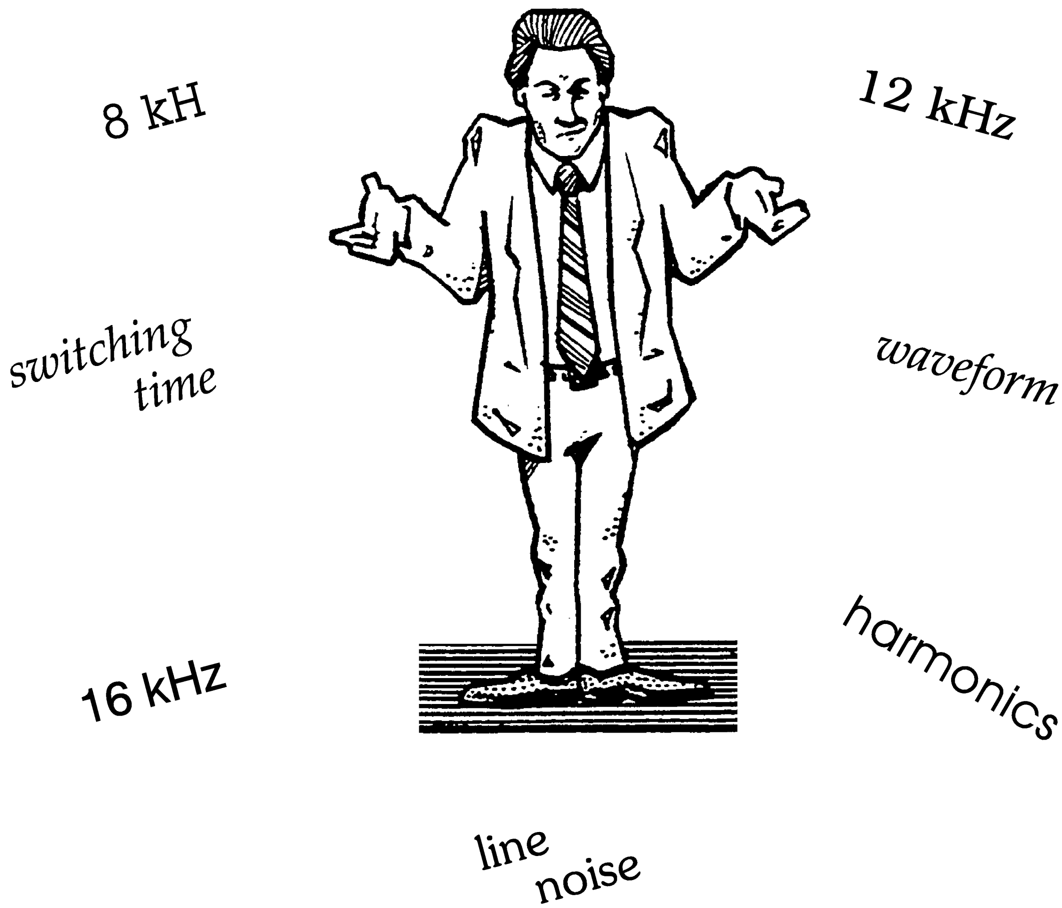
GV3000

F.A.Q's

FREQUENTLY ASKED QUESTIONS

2 Who cares about carrier frequency?



Rockwell Automation

Reliance Electric

Who cares about carrier frequency?

Q. Many IGBT drives can operate at carrier frequencies up to 16 khz. With the GV3000, the carrier frequency is limited to 8 khz. Is the limited carrier frequency a disadvantage?

A. The GV3000 is a modern A-C drive. It uses insulated-gate bipolar-transistors (IGBT's) for power switching. IGBT's allow higher carrier-frequencies than older bipolar junction transistors (BJT's). However, a higher carrier frequency is only good up to a point. The GV3000's 8 khz carrier frequency is actually an advantage.

Q. What are the benefits of a higher carrier frequency?

A. Faster switching IGBT's has two benefits.

First, an A-C drive tries to simulate line power by using "pulse-width modulation" (PWM). The higher the carrier frequency, the closer the drive comes to line power. Try to draw a sine wave by using only straight lines. You'll see that you can make a better-looking wave by drawing shorter lines, but you'll need more of them. A higher carrier frequency is similar to drawing with more lines!

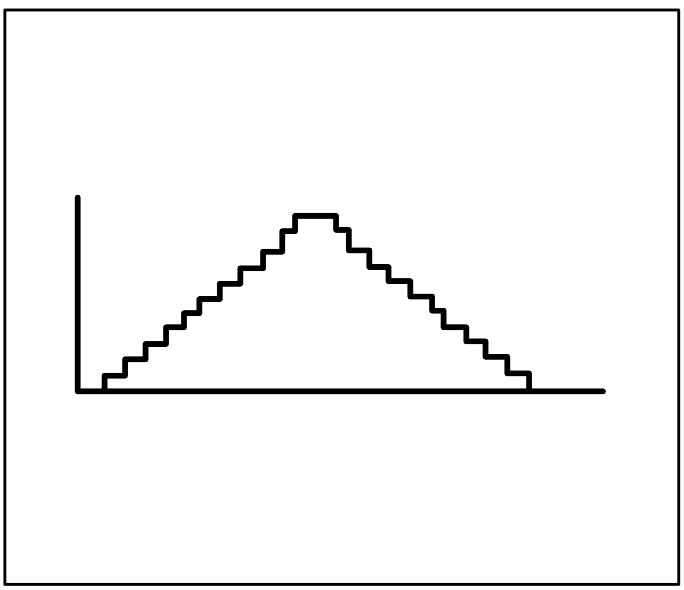


Figure 1.
Lower carrier frequency makes a crude wave-form.

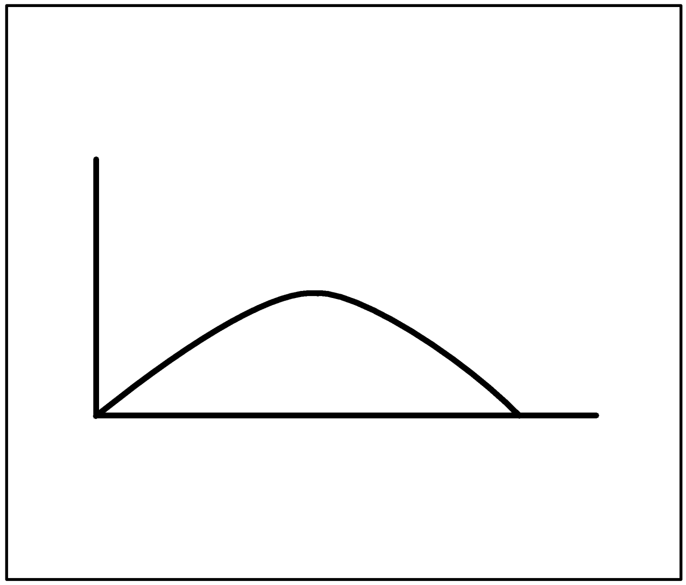


Figure 2.
Higher carrier makes a better wave-form.

Second, motors connected to A-C drives produce audible noise at a tone that is close to the carrier frequency. People hear tones in the 1–3 khz range better that they hear higher tones. (This is convenient for us since most speech tones are in this range!) Higher tones from a higher carrier frequency don't appear as loud, so there is less of the annoying "whine" that used to be associated with motors run by earlier generation A-C drives.

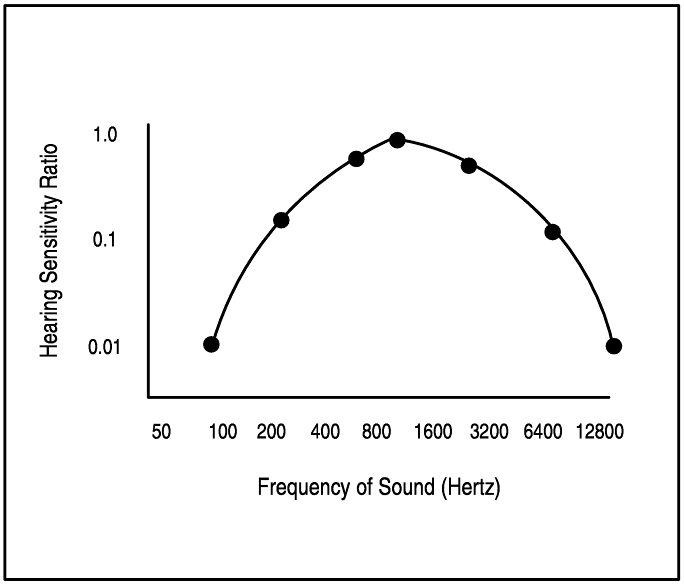


Figure 3.
Sensitivity of human hearing as a function of frequency.

Q. But you said higher is only better up to a point. What is that point, and why?

A. In a study published in 1994 by the IEEE*, the authors compared these factors at various switching frequencies:

1) Motor losses (heating in motor from operation on PWM power)

2) Harmonic losses (heating in the motor from harmonics caused by PWM power)

3) A-C drive losses (heating in the A-C drive caused by IGBT switching).

4) Audible acoustic noise

Their findings:

1) Motor losses are independent of switching frequency.

2) Harmonic losses in the motor decrease up to 10 khz, then they start to increase again.

3) A-C drive losses increase with increasing switching frequency.

4) There is a large drop in audible acoustic noise up to 6 khz. Above that, the noise level doesn't decrease much.

The IEEE study recommended 6 khz as the optimum carrier frequency for the best balance of low losses and low noise.

Q. Okay, I accept the 6–8 khz argument. Most of the A-C drive manufacturers allow me to set a lower carrier frequency. I'll specify a drive that will go to 16 khz, then set the carrier frequency to 6 or 8 khz. What's wrong with that?

A. That's an excellent question!

To be able to switch at higher frequencies, an A-C drive designer must make the IGBT's switch very quickly for two reasons.

First, switching time must be limited to a small percentage of the carrier period for stable drive operation. The carrier is shorter for a faster switching frequency, so the switching time must also be shorter.

You can simulate this by drawing. First, take your pencil and draw a dot. Now extend the dot to make a line one inch long. Make another dot, but extend this line only one-half inch. Note that the dot takes about the same amount of space each time. As your line gets shorter, more of it is taken by the dot. In a drive, the switching time (the dot) must be a small part of the carrier period (the line) or the drive won't run motors correctly.

* Audible Noise and Losses in Variable Speed Induction Motor Drives with IGBT Inverters: Influence of the Squirrel Cage Design and the Switching Frequency": A. Malfait, R. Reekman, R. Belmans, Electrical Engineering Department, K.U.L. Belgium: IEEE 1994. Proceedings of Industry Applications Society 29th Annual Meeting, Pages 693-7000. Available from Reliance Electric as D-7168.

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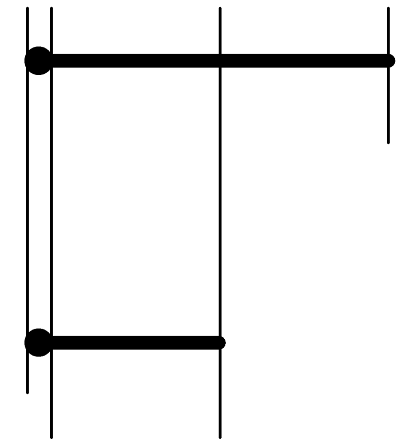


Figure 4. Dots and lines.

Drives that use “short lines” must also use “tiny dots”. A drive that permits operation to 16khz must force the IGBT’s to switch in half the time as a drive that only permits operation to 8 khz.

Second, IGBT’s are very good switches, but they’re not perfect. They produce heat while they switch. The heat makes the drive run too hot, so switching time must be minimized to allow operation at higher carrier frequencies without HP derating.

You will reduce the heat caused by switching by selecting a slower carrier frequency, but you will not slow the switching time. Carrier frequency and switching time are different!

Q. Why would I want to slow the switching time? It seems like faster switching is better, since it reduces heat.

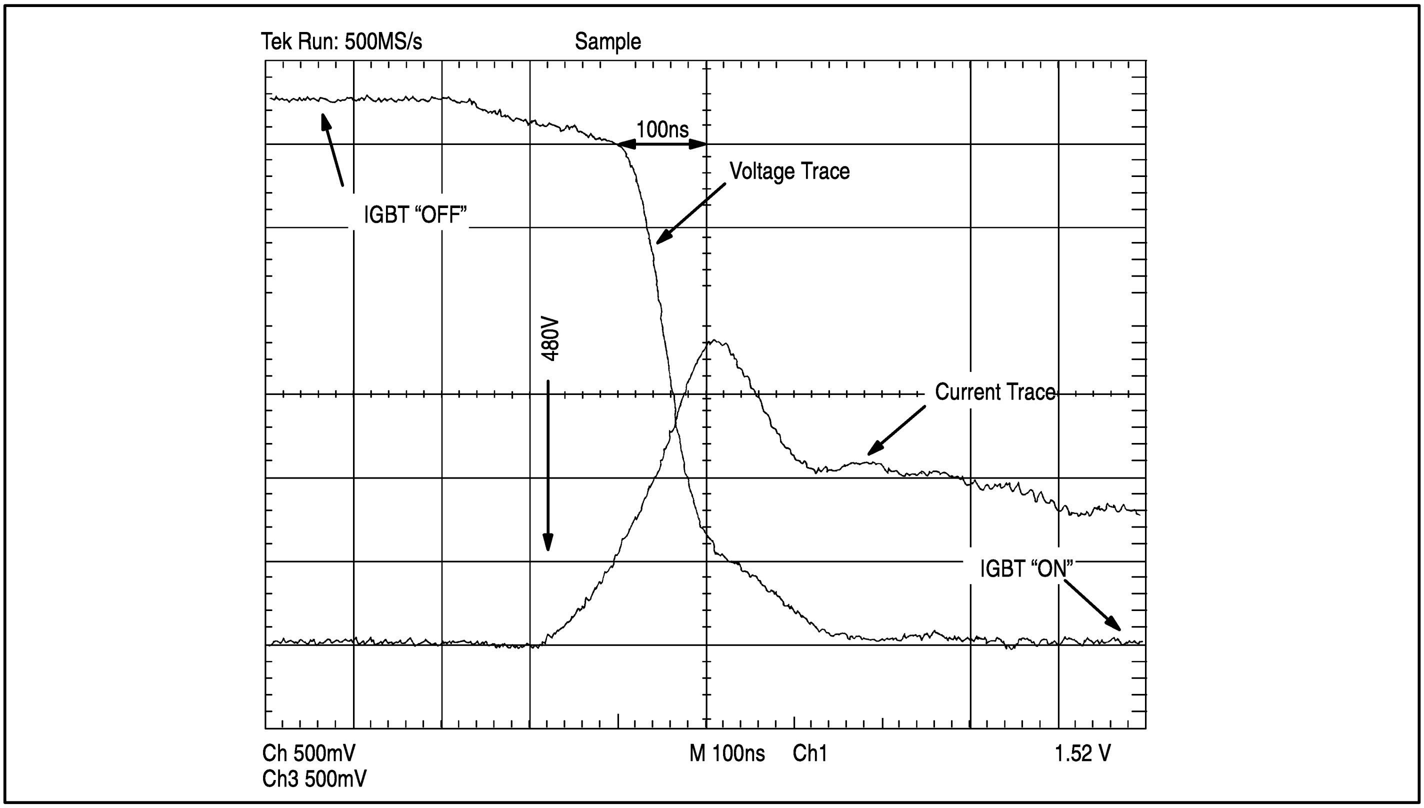
A. Once again, faster switching is better up to a point. As you noted, faster switching reduces losses that cause heat in the drive. However, motor insulation can be damaged by voltage spikes. Faster switching generates higher voltage spikes and increases the stress on the motor’s insulation system.

The GV3000 is designed to limit “dv/dt” to less than 10,000 volts per microsecond. What’s “dv/dt?” Technically, it’s the “rate of change of voltage with respect to time.” It’s the same principle that causes the ignition system in your car to generate a spark. The GV3000’s motor friendly design helps make sure that “dv/dt” doesn’t cause sparks in your motors!

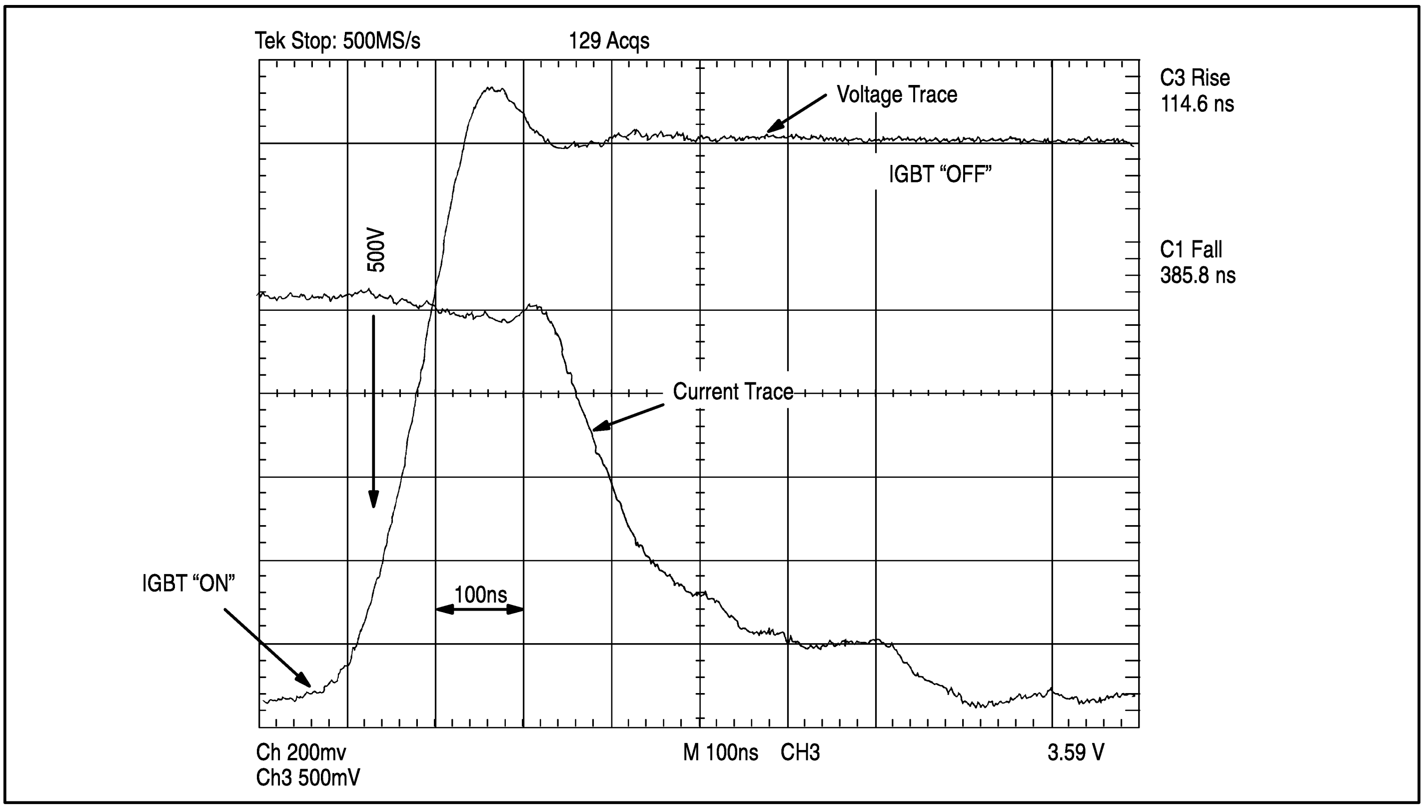
Take a look at these oscilloscope traces showing IGBT’s in action. Pay special attention to the voltage traces. The first (Figure 5) shows an IGBT turning “on.” It transitions from blocking 650 volts to conducting in 300 nanoseconds. Most of the change occurs during the middle 100 nanoseconds. The voltage across the IGBT drops by 480 volts (from 600 volts to 120 volts) during that time. That’s a “dv/dt” of 4,800 volts per microseconds

In the second trace (Figure 6), the IGBT switches “off.” It starts with almost no voltage blocking, then moves to blocking over 700 volts in about 250 nanoseconds. Once again, most for the voltage change occurs during the middle 100 nanoseconds when the IGBT blocking voltage rises by about 500 volts. That’s a “dv/dt” of 5,000 volts per microsecond.

What does all of this mean to you? Every design is a compromise. In an A-C drive, the designer must choose the optimum balance among noise, heat, motor insulation stress, smooth motor operation, and many other factors. <u>Reliance Electric, as a motor and drive manufacturer, makes decisions that consistently treat the motor and drive as a power-matched pair!</u>



Figures 5. Oscilloscope trace.



Figures 6. Oscilloscope trace.

GV3000 F.A.Q's FREQUENTLY ASKED QUESTIONS

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Measured peak voltage and dv/dt for Reliance GV 3000 Drives

Drive	Drive to Motor Distance	dv/dt (volt/microS)	Peak (volts)
GV3000 – HP	250 Ft. 500 Ft 750 Ft 1000 Ft	4400.00 2400.00 * *	1008 528 * *
GV3000 – 5 HP	250 Ft. 500 Ft. 750 Ft. 1000 Ft.	2640.00 2560.00 1280.00 1760.00	960 1056 608 976
GV3000 – 10 HP	250 Ft. 500 Ft. 750 Ft. 1000 Ft.	4240.00 1706.67 4000.00 1173.33	1040 464 1040 528
GV3000 – 50 HP	250 Ft. 500 Ft. 750 Ft. 1000 Ft.	2133.33 1600.00 2480.00 1920.00	896 992 1056 992

*Drive tripped. Output filters must be used.

Note: Data above collected from GV3000 drives during steady-state operation. Higher peak dv/dt values can occur during transient conditions.

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