THE NUANCES OF VARIABLE-FREQUENCY DRIVES

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Get an inside view of induction-motor control by varying frequency using PWM.

You can divide the world of electronic motor drives, which control the speed, torque, direction, and resulting horsepower of a motor, into two categories: ac and dc. An ac drive controls ac induction motors and, like its dc counterparts, controls speed, torque, and horsepower. A dc drive typically controls a shunt-wound dc motor, which has separate armature and field circuits. This teardown of the Schneider Electric Altivar 12 variable-frequency drive details the key features that define these drives.

AT A GLANCE

- Variable-speed drives reduce energy costs and prolong equipment life by adjusting motor speed to meet load requirements.
- Variable-frequency drives vary the voltage and frequency to an induction motor using pulse-width modulation.
- The first step is to convert the ac-supply voltage into dc using a rectifier circuit.
- The rectified dc voltage converts back to ac, typically through the use of power electronic devices, such as insulated-gate bipolar transistors.
- The output voltage turns on and off at high frequency, controlling the duration of on-time, or pulse width, to approximate a sinusoidal waveform.

Rotating equipment, including fans, blowers, compressors, and pumps, consumes more than one-third the total electrical energy generated in the United States. This equipment may use variable-speed-drive technology, in which motor speed adjusts to meet the load requirements, yielding an advantage in both improved productivity and reduced energy consumption. For example, lowering fan or pump speed by 15 to 20% enables a decrease in shaft power of as much as 30%.

Properly applied variable-frequency drives are affordable, reliable, and flexible, and they offer a significant amount of savings through reduced electric bills. Electronic variable-frequency drives vary the voltage and frequency to induction motors using pulse-width modulation. The drives use insulated-gate bipolar transistors to convert the fixed-frequency ac supply voltage to a variable-frequency, variable-voltage ac supply to the motor and can regulate the speed of an induction motor from approximately 10 to 200%; wider ranges are possible. The drives also regulate the output voltage in proportion to the output frequency to provide a relatively constant ratio of voltage to frequency to produce adequate torque.

The Altivar 12 manual recommends that you remove the vent covers for IP (ingress protection) Type B and C mounting when IP20 protection is adequate but that you leave them on the housing in Type A mounting (**Figure 1**). ANSI/IEC 60529-2004 describes the degrees of protection provided by enclosures. It is a system for classifying the degrees of protection for operators against access to hazardous parts and protection of equipment against the ingress of solid foreign objects and water. Type A mounting allows for free space of more than 50 mm (1.97 in.) on each side, with vent covers in place. Type B mounting allows for side-by-side-mounted drives with removed vent covers (**Reference 1**). Type C mounting matches that of Type A but with removed vent covers.

The first step is to convert the ac-supply voltage into dc using a rectifier circuit. The dc power contains voltage ripples, which filter capacitors smooth (**Figure 2**). This dc voltage then converts back into ac, typically using pulse-width modulation (**Figure 3**). The output voltage turns on and off at a high frequency, with the duration of on-time, or pulse width, controlled to approximate a sinusoidal waveform.

The Altivar 12 series uses the Infineon FP30R06W1E3 IGBT module and has a well-designed heat-sink assembly. The Infineon IGBT module uses an Al_2O_3 substrate, which gives the case a low thermal resistance that is critical to the reliability and long-term performance of the system. Aside from the input converter's diode bridge and output inverter with IGBTs, this Infineon module also has an NTC (negative-temperature-coefficient) thermistor onboard for temperature monitoring of the heat sink and an Easy PIM (personal-information-manager) module (**figures 4**, **5**, and **6**).

The integrated three-phase gate driver for the IGBT assembly is the Infineon 6ED003L06-F, which features a thin-film silicon-on-insulator technology that makes the six-IGBT-bridge output insensitive to negative transient voltages as high as –50V (**Figure 7**).

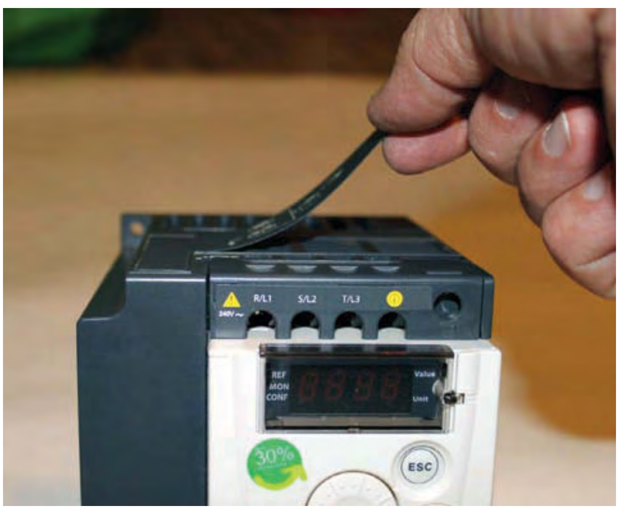

Figure 1 Remove the vent covers for Type B or C mounting when IP20 protection is adequate, but leave them on the housing in Type A mounting.

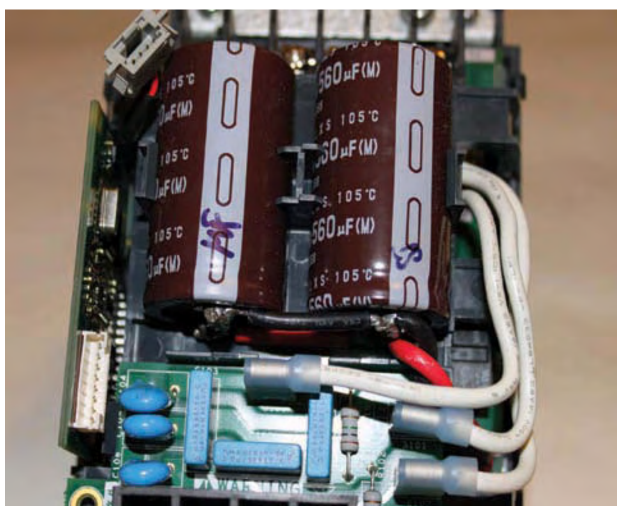

Figure 2 The dc link, or dc-bus filter, comprises a series inductor and two filter capacitors in parallel with associated MKP-type capacitors, which are in series with the mains.

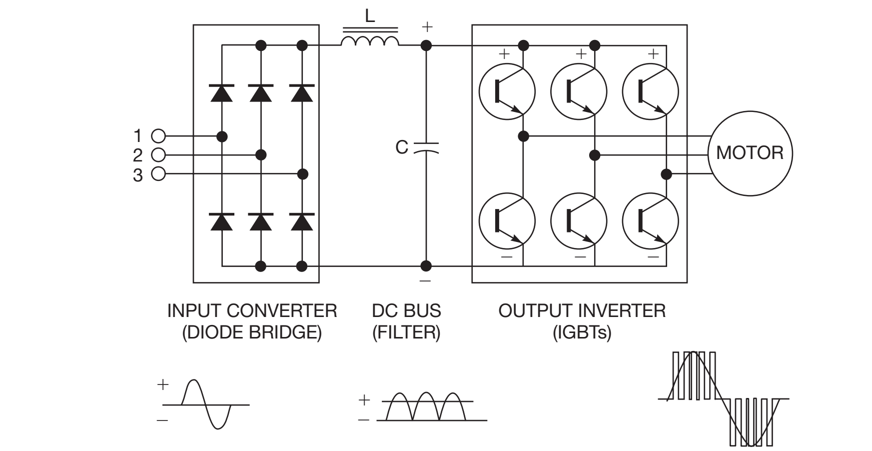

Figure 3 IGBT power transistors can convert the dc voltage back into ac using pulse-width modulation.

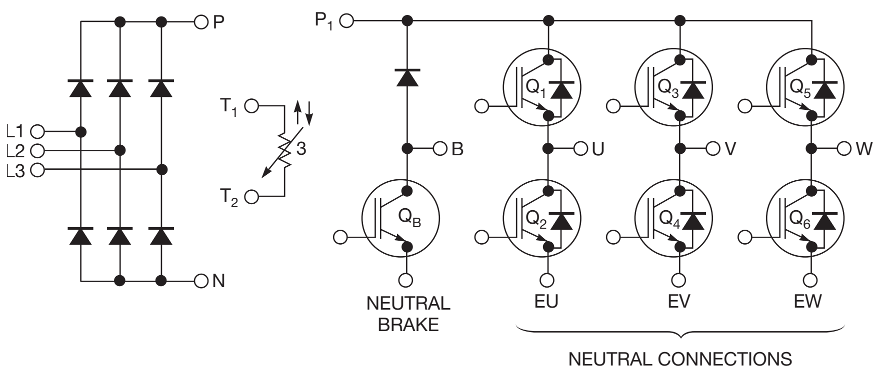

Figure 4 The Infineon FP30R06W1E3 includes rectifier diodes, an NTC thermistor, and IGBTs.

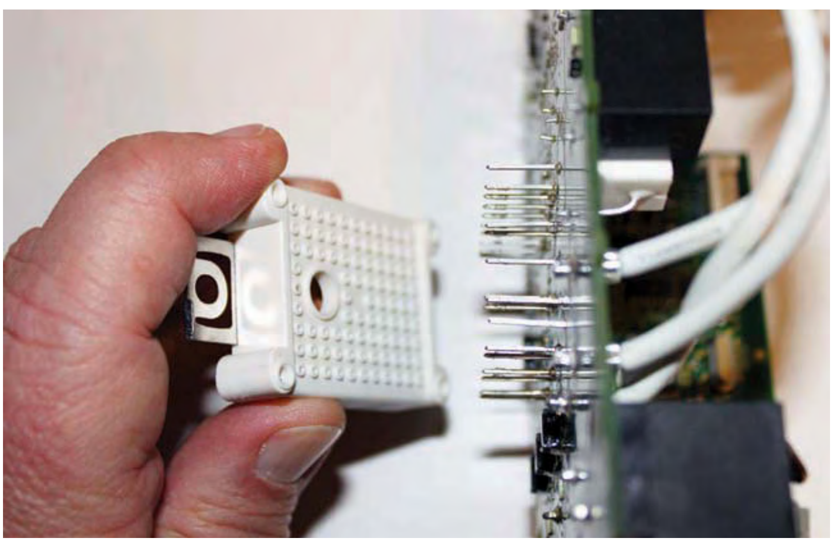

Figure 5 You can easily assemble the Infineon Easy PIM module as a plug-in module on the back of the IGBT-gate-driver card.

Figure 6 The Altivar 12 heat-sink assembly for the Infineon Easy PIM module mechanically connects on the flat rear surface of the heat sink and thermally connects with thermal grease.

Motor-drive applications require galvanic isolation for the IGBTs' gate drive for bridge inverters and for motor-phase current sensing. In this case, the SOI substrate is fully isolated from the rest of the circuit. The high-voltage precharge circuit minimizes the peak current from the power source by slowing down the dV/dT of the input-power voltage, thus implementing a new precharge mode.

You must switch off the inductive loads on the distribution system during the precharge mode. During precharging, the system voltage rises slowly and controllably, with power-up current never exceeding the allowed maximum. As the circuit voltage approaches near steady state, the precharge function completes. The normal goal of a precharge circuit is to terminate precharge mode when the circuit voltage is 90 or 95% of the operating voltage.

Upon completion of precharging, the precharge resistance switches from the power-supply circuit and returns to a low-impedance power source for normal mode. The high-voltage loads then power up sequentially. This step keeps the capacitor from overstressing. When you apply dc power to a capacitor, the capacitor instantly sees this action as a short circuit, causing a large inrush current from the source (**Figure 8**).

A microprocessor controls the

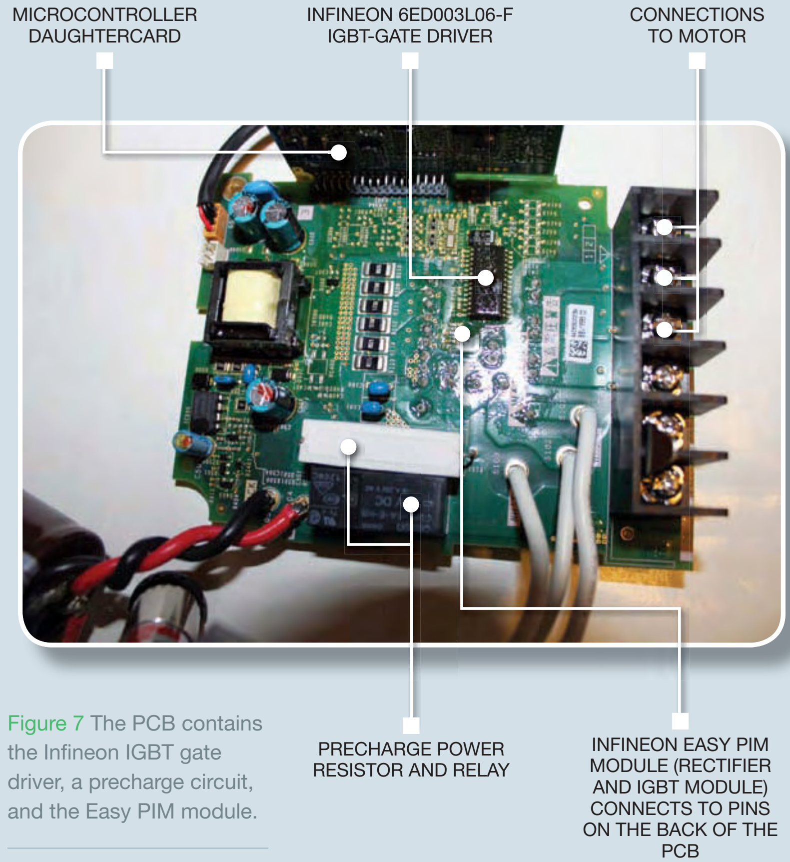

Figure 7 The PCB contains the Infineon IGBT gate driver, a precharge circuit, and the Easy PIM module.

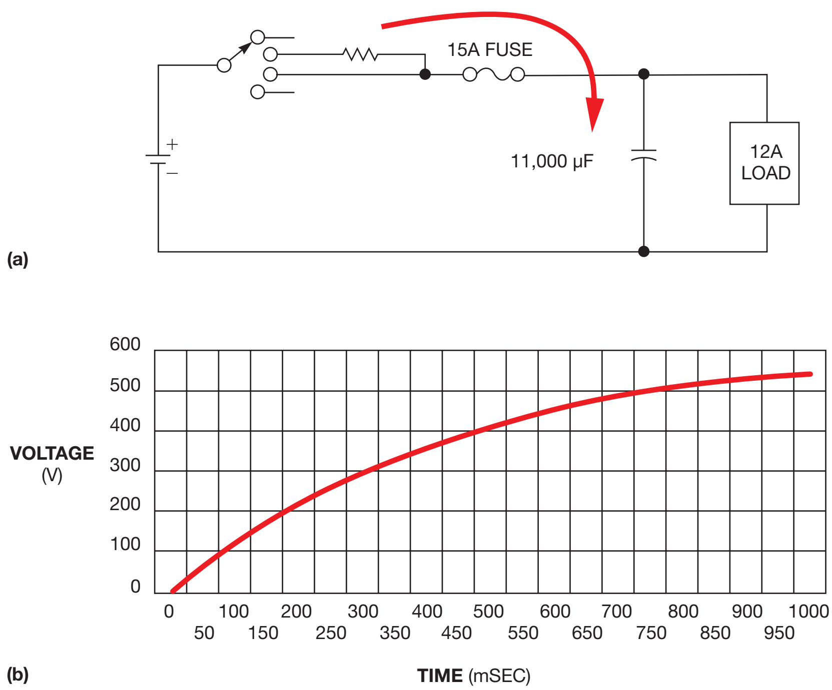

Figure 8 A precharging example (a) shows how the relay switches in a power resistor to limit inrush current to the capacitor, thereby extending capacitor life (b).

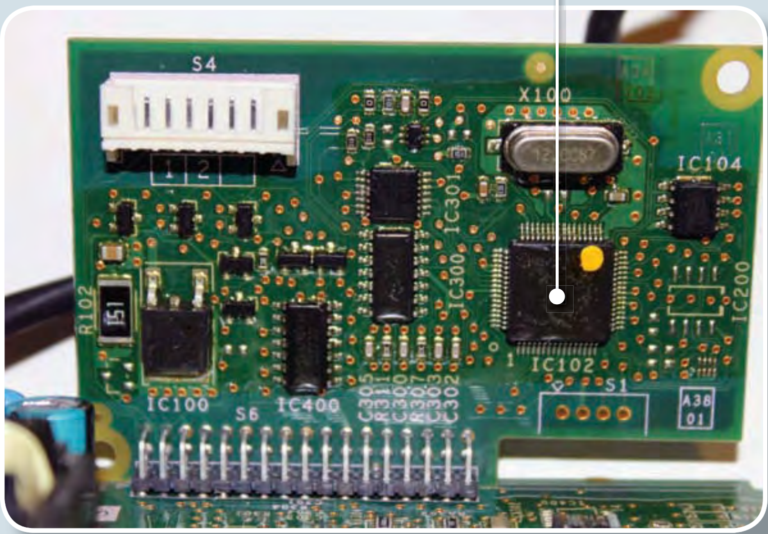

Figure 9 The microcontroller's daughtercard performs the inverter function.

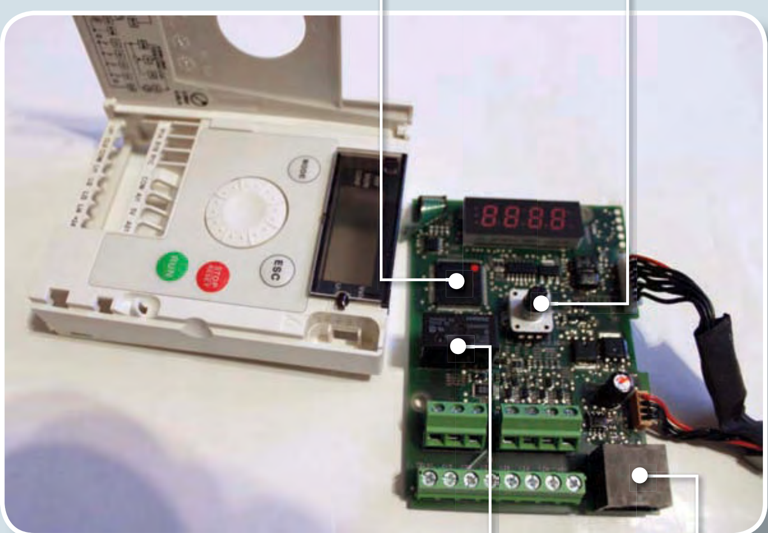

Figure 10 The display board normally resides behind the front panel, and a Renesas microcontroller drives and controls the display and the Modbus-serial-port connection.

process by monitoring the incoming voltage supply, speed setpoint, dc-link voltage, and output voltage and current to ensure operation of the motor within established parameters. The Altivar 12 designers used the 32-bit RISC Renesas R5F71253VD50 microcontroller SuperH device, which incorporates timer units that generate three-phase PWM waveforms with dead time and a 12-bit ADC for inverter control (**Figure 9**).

THE DEVICE USES A MODBUS SERIAL PORT TO CONNECT TO EXTERNAL SOFTWARE, THE MODBUS INDUSTRIAL NETWORK, OR A REMOTE DISPLAY. THIS MULTIFUNCTION DESIGN SAVES SPACE AND COST.

The device uses a Modbus serial port to connect to external software, the Modbus industrial network, or a remote display (**Figure 10**). The 16-bit Renesas R5F3640 microcontroller handles the display functions and translates motor- and drive-status conditions to display messages. The potentiometer connects to the front-panel jog dial and acts as a potentiometer in local mode for navigation when clockwise or counterclockwise and selection and validation when pushed. This multifunction design saves space and cost. The Omron G5RL power relay provides remote indication of drive status on the board.**EDN**

REFERENCE

1 "IP-Ingress Protection Ratings," The Engineering ToolBox, http://bit.ly/GLW5LK.

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