Ultra-Compact Inverter FVR-C9S

Kazuhiko Imamura
Takao Ichihara
Osamu Shiokawa

1. Introduction

The application of standard inverters for general use can be divided into two categories: improving general-use industrial machinery to make them high-function and high-performance, and for simple speed changes in small fan pumps, mini-conveyers, or the replacement of mechanical variable-speed drives.

In pursuit of the latter application, which promises great potential demand, seven models of then inverter FVR-C9S series have been developed. Ultra-compact size, low price, simple operation, and ultra-low noise are the major features of this inverter series.

2. Features

Figure 1 shows the external view of the FVR-C9S inverter.

2.1 Ultra-compact design

This new inverter series, a reduction to about 60% in installation area and 50% in volume (for 0.75 kW use) of Fuji Electric's inverter FVR-E7S series, previously the smallest inverter series, has been attained. A comparison of the external dimensions of the FVR-C9S to the FVR-E7S is shown in Table 1.

Fig. 1 External view of the FVR-C9S

The external width and height have been standardized to 80 mm and 120 mm, respectively, for 0.1 to 0.75 kW types. This device can also be fixed to a rail (optional) as an electromagnetic contactor or a circuit breaker for wiring.

2.2 Ultra-low noise

The electromagnetic noise of a motor often becomes a problem when it is driven by an inverter. By using IGBTs in all models of this inverter series, noise can be kept to the same level as that which the motor generates when driven by commercial power source. This feature makes the product environmentally friendly, and thus the inverter series is expected to expand its share in the home appliance field.

2.3 Simple operation

The dial for setting frequency and the keypad switches for "run" and "stop" are located on the front side of the inverter, allowing variable-speed operation of the motor by simply connecting the power lines. Although the input and output terminals have been reduced to the minimum necessary for the applications, functions for electronic thermal overload relay, restarting after momentary power failure and jump frequency are provided as standard so the inverter can be applied to general uses.

Table 1 Comparison of external dimensions

Standard applicable motor	Object of comparison	FVR-E7S	FVR-C9S	Ratio
0.2 kW	Dimensions (mm)	105×150×80	80×120×65	–
	Installation area (cm^2)	158	96	60%
	Volume (cm^3)	1,260	624	50%
0.4 kW	Dimensions (mm)	105×150×90	80×120×75	–
	Installation area (cm^2)	158	96	60%
	Volume (cm^3)	1,418	720	51%
0.75kW	Dimensions (mm)	105×150×119	80×120×100	–
	Installation area (cm^2)	158	96	60%
	Volume (cm^3)	1,874	960	51%

Table 2 Specifications of the inverter FVR-C9S series

Model (FVR □□□C9S-2)		0.1	0.2	0.4	0.75	1.5	2.2	3.7
Standard applicable motor output *1 (kW)		0.1	0.2	0.4	0.75	1.5	2.2	3.7
Output ratings	Rated capacity*2 (kVA)	0.28	0.56	1.0	1.6	2.8	4.0	6.6
	Rated voltage	200 to 230 V, 50/60 Hz (Output voltage is proportional to input voltage.)						
	Rated current (A)	0.7	1.4	2.5	4.0	7.0	10.0	16.5
	Overload rating	150%, 1 min						
	Rated frequency (Hz)	50/60 Hz						
Input ratings	Power supply	Three-phase, 200 to 230 V, 50/60 Hz						
	Allowable variation	Voltage: +10 to –15% (Unbalance shall be less than 3%), Frequency: ±5%						
	Allowable momentary voltage drop	More than 165 V: Continued operation Voltage drops from rated voltage to 165V: Continued operation for 15 ms*3						
	Required capacity (kVA)*4	0.3	0.7	1.2	1.8	3.2	4.5	7.3
Output frequency	Ajust-ment: Max. frequency	50 to 120 Hz variable (1 Hz step)						
	Ajust-ment: Base frequency	50 to 120 Hz variable (1 Hz step)						
	Ajust-ment: Starting frequency	1 to 6 Hz variable (1 Hz step)						
	Accuracy	Analog setting: ±1.0% of max. frequency (25±10℃) Digital setting: ±0.01% of max. frequency (–10 to +50℃)						
	Setting resolution	Analog setting: 1/256 of max. frequency (e.g. 0.25 Hz/60 Hz, 0.5 Hz/120 Hz) Digital setting: 0.1 Hz (Under 99.9 Hz), 1 Hz (100 to 120 Hz)						
Control	Control system	Sinusoidal PWM control (ultra-low motor noise from high-frequency carrier)						
	Operation	Keypad: Operation by RUN, STOP key Input signal: Forward, Reverse, Free run, Reset, External alarm input						
	Frequency setting	Keypad: Setting by △, ▽ key Terminal for potentiometer: Equipped for 1 to 5 kΩ potentiometer for VR Analog Signal: DC0 to +5 V, DC0 to +10V (Z_{in}=22 kΩ) (With optional card, signal of DC4 to 20mA is available.)						
	Disp-lay: Running	Digital display (3 digit LED): Output frequency or output current.						
	Disp-lay: Protective trip	Display (3 digit LED): By cause of protective trip.						
	Disp-lay: Others	LED is lit while DC link is charged.						
	Acceleration/deceleration time	0 to 60 s (Variable······Acceleration and deceleration time are independently set.)						
	V/f characteristic	Variable setting of max. frequency / base frequency						
	Restart after momentary power failure	By setting automatic restart, restart is performed without stopping motor.						
	Torque boost	32 steps variable						
	Other functions	High/low limiter, Gain/bias setting, Jump frequency, Jump frequency range, Noise						
	Starting torque	More than 150%						
Brake	Brake torque*5	More than 150%		More than 100%		More than 50%	More than 30%	
	DC brake	DC brake start frequency: 3 Hz (fixed). DC current and DC brake time are variable.						
Protection		Overcurrent, Overvoltage, Undervoltage, Ground fault (detected at starting), Short circuit, Heat sink overheat, Electronic overload relay						
Environment	Installation location	Indoor, Altitude: Less than 1,000m above sea level. Do not install in a dusty location or expose to corrosive gases, oil mist.						
	Ambient temperature	–10 to +50℃						
	Humidity	20 to 90%RH (Non-condensing)						
	Vibration	Acceleration: 5.9 m/s² or less, Vibration frequency: 5 to 55 Hz						
	Strage temperature	–25 to +65℃						
Degree of protection (JEM 1030)		IP 20 enclosure type						
Cooling system		Self-cooling				Forced air-cooling		

*1 Values are for 4 pole motor.
*2 Values at 230V.
*3 Values are for momentary failure at 80% load with rated voltage applied.
*4 Values are for standard motor with optional ACR.
*5 Average brake torque with no loaded motor. (Varies depending on motor efficiency)

2.4 Improvement in environmental resistivity

All components for the power and control circuits are resin-molded to better withstand humidity and dust in the environment.

3. Specifications and Circuit Configuration

3.1 Specifications

The specifications of the inverter FVR-C9S series are shown in Table 2. The functions needed for the intended applications of each inverter model can be provided as either standard or optional.

3.1.1 Setting reference frequency

In addition to digital setting of the reference frequency, a potentiometer also comes standard to simplify analog setting of the reference frequency. For remote setting of the reference frequency, there is also voltage input (standard) and current input (optional). Other major functions include a high/low limiter and a gain/bias setting.

3.1.2 Electronic thermal overload relay

The electronic thermal overload relay function, which can be used with either the standard motor or the Fuji FV motor, protects the motor against overload and improves reliability in operation.

3.1.3 Restart after momentary power failure and retry

In addition to the "restart after momentary power failure" function, the retry function is provided, which automatically restarts equipment necessary for continuing operation even after the overcurrent protection or overvoltage protection is operated.

3.1.4 DC braking

DC braking is a useful function which prevents the motor from free run prior to stopping when it is being decelerated to a stop. To achieve stable braking, current is controlled with current feedback.

3.1.5 Other functions

The frequency jump function, which prevents mechanical resonance of the machinery and motor, torque boost adjustment, acceleration or deceleration time adjustment, and control of motor operation noise are also included in the 26 total functions of this inverter series.

3.2 Circuit configuration

The circuit configuration of the inverter FVR-C9S series is shown in Fig. 2. IGBTs are used in all models of the series, and system control is done by a one-chip CPU. The current is detected with a shunt resistor, the voltage with a DC link divider, thus reducing the number of parts.

4. Component Technology for Miniaturization

4.1 Development of a combined metal board with different insulation substrates

The power transistor, rectifier diode, and other

Fig. 2 Circuit configuration of the FVR-C9S

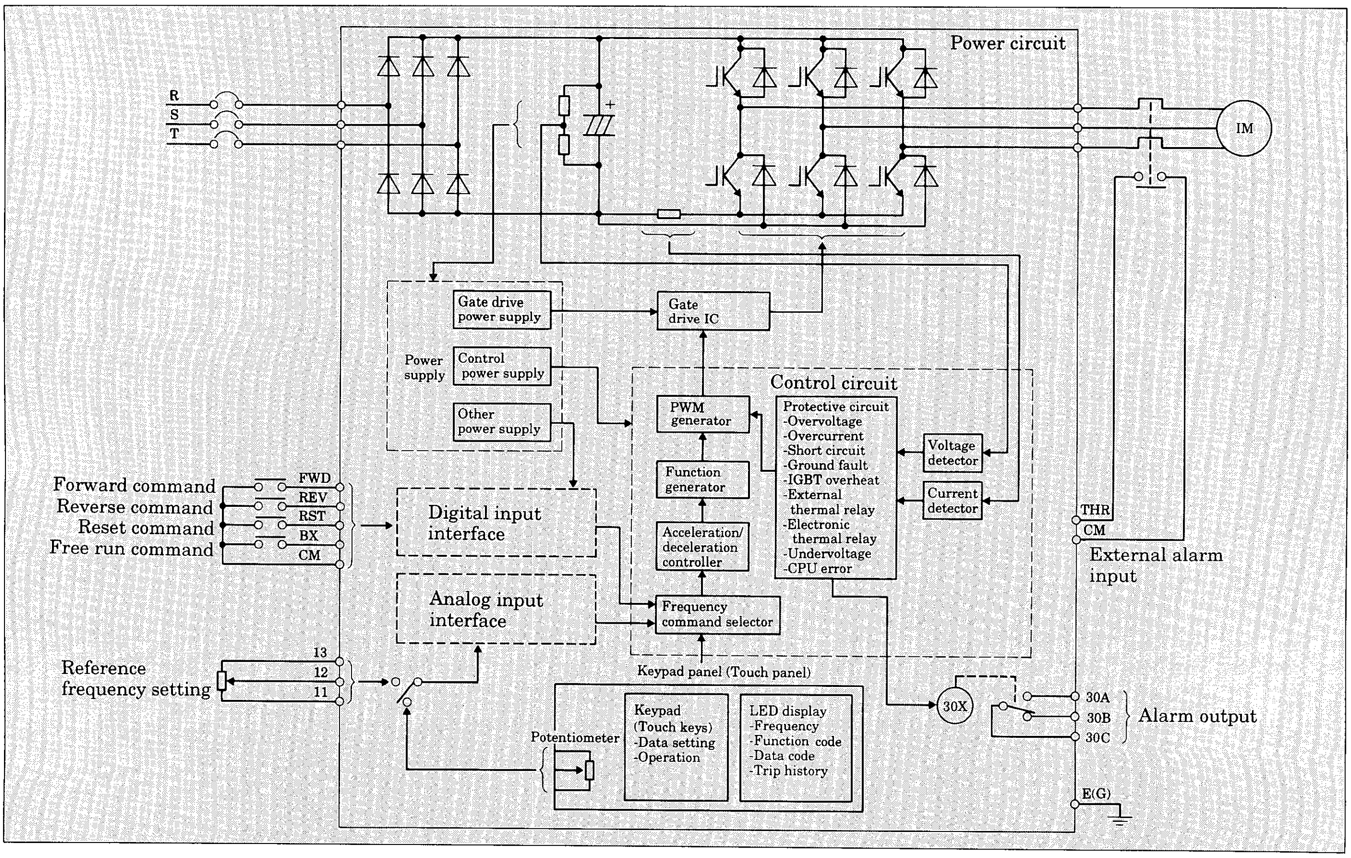
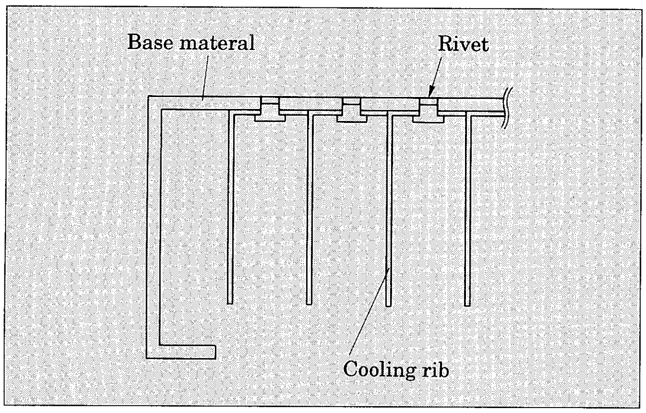


Fig. 3 Cross section of a heat sink



components of the power circuit which generate large heating losses were conventionally mounted on a metal or ceramic board which use insulation material having low heat resistance. The components for both the control circuits and control power supply circuits were mounted on an epoxy glass board having a low dielectric constant, and the power circuits and control circuits were each connected with connectors. But the heat resistance of the epoxy glass board was so high that it was unsuitable for the mounting heat-generating components, and the interconnections between units created more work in the manufacturing process. To solve these problems, a combined metal board with different insulation substrates has been developed, which consists of a single metal board on which insulation material having different characteristics are arranged. By using this board, improvement in the cooling efficiency of components and miniaturization of the inverter were made possible.

4.2 Development of metal QFP

For further miniaturization of the control circuits, a compact package made of a metal substrate formed into a box by press work was developed. The CPU, gate drive circuit, and various detection circuits were highly integrated into this package.

4.3 Development of a pressed heat sink

The heat sink of an inverter is generally manufactured by the aluminum diecast method. The problems with the method are:

(1) The rib length is limited by the die strength.
(2) The thickness of the rib is limited by the casting.

To solve these problems, a heat sink made of aluminum by combined press work has been developed. Cooling ribs of pressed, relatively thin aluminum plates are riveted to a thicker aluminum base plate. Figure 3 shows a cross section of the pressed heat sink.

This pressed heat sink is 41% the volume and 57% the weight of a conventional aluminum diecast heat sink (for 0.75 kW use).

Fig. 4 Application to a pump system

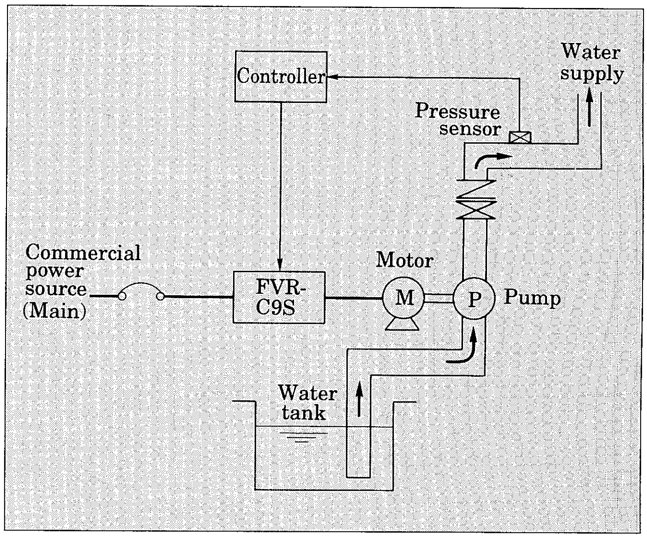
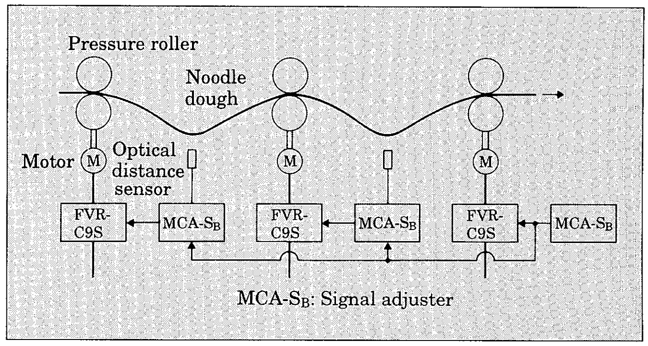


Fig. 5 Application to a noodle machine



5. Application Examples

5.1 Pump system

In a pump system, the flow rate and pump pressure are needed to control the pump depending on the amount of water supplied. The inverter is suited for controlling the pump rotation speed, as it can control the motor speed simply and effectively.

Figure 4 shows constant pressure control of a pump system using an inverter. A sensor detects the pressure of the water supply system, and the inverter adjusts the rotation speed of the pump to keep the water pressure constant even if the amount of water changes. At low rotation speeds, at which the water supplied is small, the pump driving torque is reduced, resulting in a high level of energy saving.

5.2 Conveyer

In a product assembly line, conveyers are required to keep the carrier speed at an optimum rate according to the assembly time of the product. This important function has conventionally been controlled by pulley or mechanical variable-speed drives. Such speed control can easily be done by simply turning the dial of the reference frequency of an inverter. This frequency setting dial comes as standard equipment on the FVR-C9S inverter. Work preparation time can be saved by using the inverter, which is especially advantageous when the production line involves making small quantities of a variety of product types.

Furthermore, the conveyer manufacturer does not need to provide special pulleys or variable-speed drives specific to 50Hz/60Hz application, and thus parts inventory can be reduced.

5.3 Noodle machine

A noodle machine has several pressure rollers which roll and extend the dough continuously to make the noodles. If the noodle dough hangs too loosely between the rollers, or hangs too tightly and the noodle breaks, resulting in defective noodles. Using an optical distance sensor, the inverter can control the rotation speed of each pressure roller according to the amount of dough hanging between the rollers. This is shown in Fig. 5. This system has been successful in creating consistency in noodle production

6. Conclusion

The ultra-compact inverter FVR-C9S series has been developed for the market. It is expected that this will expand the range of application for inverters to the smaller capacity ratings of 100W or less and in home automation, areas previously excluded from inverter application due to cost and size concerns. The authors will further endeavor to develop a single-power supply model and to make this inverter series adaptable to EMC (Electromagnetic Compatibility) technology.