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GENERAL PURPOSE INVERTER FVR-G5

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1 FOREWORD

The applications of the general purpose inverter as a standard motor variable speed device are increasing steadily. The FVR-G5/P5 series are digital inverters developed for high performance, functionality, low cost, easy use, and high reliability by pursuing utilization technology. To meet the applications, uses, and other demands of the market, their functions have been expanded based on control and structural specifications and application to a wide range of industrial fields has been made possible. The features of this series are described below.

2 SPECIFICATIONS

Exterior views of the FVR-G5 series are shown in *Fig. 1*. Its standard specifications are listed in *Table 1*.

2.1 Expansion of product series functions

The FVR series is made up to numerous models to allow optimum use. That is, the 0.4 to 3.7 kW (1.2 to 6 kVA) series is based on two control specifications (standard type and popular type) and two structural specifications (standard type and panel space saving type) and has the optimum model composition for replacing the old G2 series. The 5.5 to 22 kW series is standard type and consists of the constant torque G5 series (overload 150% for 1 minute) and 11 to 22 kW fan and pump P5 series (overload 120% for 1 minutes). An exterior view is shown in *Fig. 2*. The number of models with a capacity of

Fig. 2 FVR-G5 standard type exterior view (5.5 ~ 22 kW)

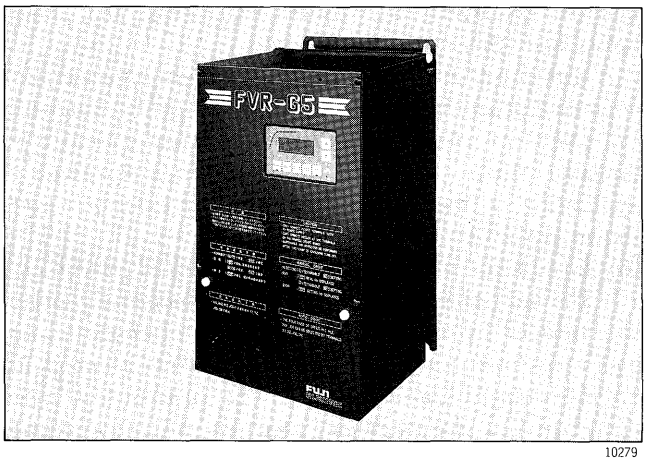

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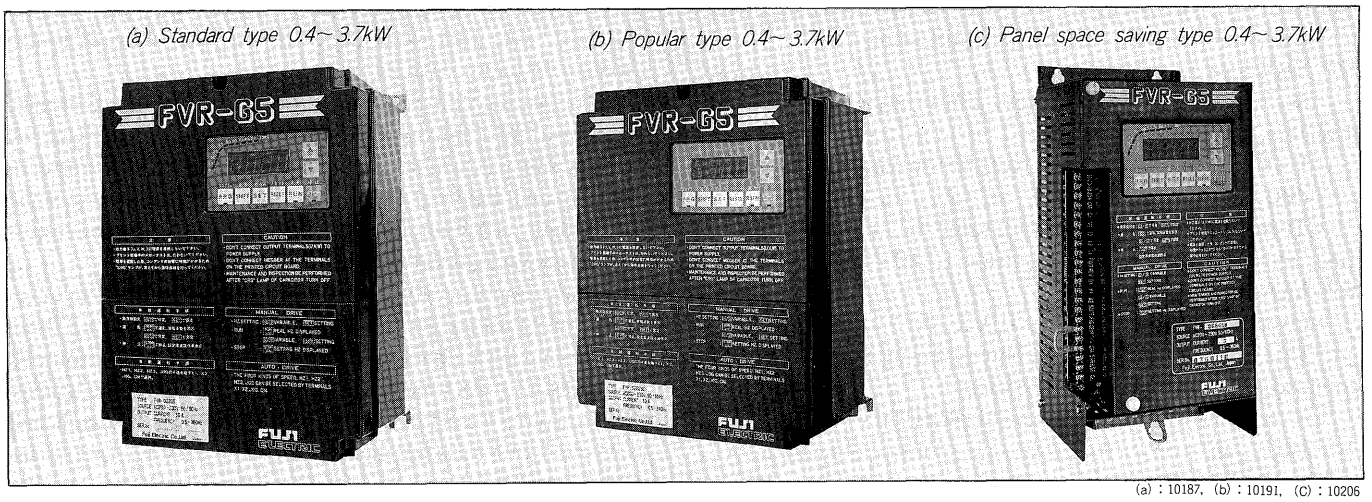
Fig. 1 FVR-G5 series exterior views



(a) : 10187, (b) : 10191, (c) : 10206

Table 1 FVR-G5 standard series specifications

Inverter type			Standard type										
			FVR 004G5-2	FVR 008G-2	FVR 015G-2	FVR 022G-2	FVR 037G-2	FVR 055G-2	FVR 075G-2	FVR 110G-2	FVR 150G-2	FVR 185G-2	FVR 220G-2
Applied motor (kW)			0.4	0.75	1.5	2.2	3.7	5.5	7.5	11	15	18.5	22
Rated capacity (kVA)			1.2	2	3	4	6	9	13	17	22	28	33
Rated current (A)			3	5	8	10	16	24	33	45	58	73	86
Input	Voltage and frequency		3-phase, 3-wire system 200~230V 50/60 Hz (1φ input possible for 1.2 kVA only)										
Input	Variations		Voltage: 180~253V, Frequency: ±5%										
Output	Voltage		3-phase, 3-wire system 200V, 200V, 230V (input voltage proportional correspondence) Constant output by option (OPC series)										
Output	Frequency (Hz)		50, 60, 100, 120, 150, 180, 200, 240, 300, 360							50,60,100,120,150,180,200,240 option			
Control system			Sinusoidal PWM control										
Frequency control range			0.5~360 Hz							2~240 Hz			
Frequency accuracy			Digital setting: ±0.02% (25±10°C) of maximum frequency, analog setting: ±0.5% (25±10°C) of maximum frequency										
Frequency resolution			0.01 Hz (analog setting: 0.02 Hz at 60 Hz)										
Voltage/frequency ratio			V/F pattern switching (19 patterns), V/F magnitude switching (16 steps), square reduction torque correspondence										
Standard functions			50~99 Hz base frequency setting, automatic V/F, automatic torque boost, three frequency jumps, upper and lower limiters, bias control, current control										
Overload capacity			150% for 1 minute										
External output signal			Alarm output signal (1c contacts, AC250V, 2A), inverter stop, frequency match, overload alarm signal (open collector output)										
Soft start and stop			0.06~1,800s (32 steps, acceleration/deceleration independent)										
Operating system			Touch panel [RUN] [STOP] operation										
			Forward/reverse operation (FWD terminal, REV terminal), free running stop (BX terminal)										
Frequency setting signal			Touch panel [△] [▽] operation, remote operation by X1, X2, JOG terminals, variable JOG (60 kinds) selection										
			Multiple setting DCO – +10V, DCO ––10V (input impedance 22kΩ) and DC4~20mA (input impedance 250Ω)										
Braking torque (short-time rating)			Regenerative braking 150% or more			Regenerative braking 100% or more		Regenerative braking 40% or more		Regenerative braking 20% or more			
			DC dynamic brake on/off selection (0.5 Hz or less, 2 Hz or less for 11 kW or higher)										
Protection functions	Stall prevention		Motor stall is avoided by forecasting the load conditions and suppressing the voltage.										
Protection functions	Inverter tripping	Inverter overheating	Inverter internal overheating by overload and external DB overheating (DB terminal) are detected.										
Protection functions	Inverter tripping	Overload	Motor overload detected (electronic thermal relay, external thermal relay)										
Protection functions	Inverter tripping	Overcurrent	Overcurrent at motor acceleration, deceleration, and constant speed is detected.										
Protection functions	Inverter tripping	Overvoltage	Regenerative voltage at deceleration is detected.										
Protection functions	Inverter tripping	Low voltage	Commercial power low voltage is detected.										
Protection functions	Momentary power interruption		Operation continued for a momentary commercial power interruption of up to 15 ms.										
			Inverter stops for a momentary commercial power interruption exceeding 15 ms.										
Protection functions	Output terminals shorting and grounding		Inverter output terminals shorting protection function, inverter output terminals grounding protection function.										
Protection functions	External thermal relay		Inverter stopped by thermal relay contacts (Operates as an external relay while inverter operating and operates as external reset while inverter stopped)										
LED display	7-segment character display	Operating mode	Actual frequency (Hz) or average effective current (A) selecterble										
LED display	7-segment character display	Setting mode	Set data display (function code)										
LED display	7-segment character display	Alarm mode	OU: Overvoltage, LU: Undervoltage, OH1: Inverter overheating, OC1: Overcurrent at acceleration, OC2: Overcurrent at deceleration OC3: Overcurrent during operation, OL1: External thermal relay operated, OL2: Electronic thermal relay operated, Err1: CPU erroneous operation										
LED display	Level meter display		Actual frequency (Hz) by 0~100% (10% increments) % display										
Environment	Location		Indoors altitude 1000m or lower, no harmful gases or dust										
Environment	Ambient temperature		–10~+40°C (inside panel –10~+50°C, with ventilation covers at top and bottom of front panel removed)										
Environment	Ambient humidity		Relative humidity 90% or less (no condensation)										
Construction			Unit type with totally enclosed case										
Cooling system			Natural cooling	Natural cooling	Natural cooling	Forced cooling	Forced cooling	Forced cooling	Forced cooling	Forced cooling	Forced cooling	Forced cooling	Forced cooling
General weight (kg)			3.1	3.2	5.7	6.0	6.2	12.1	13.1	17	18	21.5	22.5

3.7 kW or less is specially large. This series meets market demands for multiple functions, higher performance, and low cost.

2.1.1 Control specifications

There are two series, standard type, which pursues multiple functions, and popular type, which demands low cost for general applications. The control system utilizes the features of each series.

2.1.2 Structural specifications

(1) The 0.4 to 3.7 kW low capacity series consists of two types: totally enclosed type and enclosed type. This series can be optimally used according to the installation site.

(2) The 5.5 to 22 kW medium capacity series protection structure is enclosed type. The installation dimensions of the old series have been observed are small size and light weight realized.

2.2 Low cost

This series was developed mainly to reduce the number of parts.

The main points are described below.

2.2.1 PC board miniaturization

(1) A full custom LSI (10,000 gates) was developed and installed.

(2) The DC-DC converter was simplified by using a new base drive circuit system.

(3) A hybrid IC containing a power circuit was developed and used.

(4) The interface section was simplified by using a new circuit system.

(5) DDC (Direct Digital Control) realized and PC board adjustment eliminated by 16 bit CPU, 4 bit CPU, full custom LSI, and NOVRAM. Compact touch panel used as the operating section.

Table 2 Functions

Function code		Data code			Inverter model	
▨▨□□	Outline of function	□□▨▨	Display contents	Preset code	Popular type G5E	Standard type G5
00	Panel display characters switching at operation	00	Output frequency (Hz)	00	○	○
		01	Output current (average value) (A)		–	○
01	Multi-stage speed 1 setting	00~60	Setting 1 operating frequency (Hz)	10	○	○
02	Multi-stage speed 2 setting	00~60	Setting 2 operating frequency (Hz)	20	○	○
03	Multi-stage speed 3 setting	00~60	Setting 3 operating frequency (Hz)	30	○	○
04	Jogging operation frequency setting	00~60	Jogging operation frequency (Hz)	05	○	○
05	Acceleration time setting	00~31	Acceleration time data code No.	12	○	○
06	Deceleration time setting	00~31	Deceleration time data code No.	12	○	○
07	2nd acceleration/deceleration time	00~01	Acceleration/deceleration time data code No.	12	○	○
08	Electronic thermal relay setting	00~14	Set value data code No.	00	–	○
09	Torque boost setting	00~15	Torque boost data code No.	08	○	○
10	Frequency pattern setting	00~15	Frequency pattern data code No.	01	○	–
		00~08			–	○
11	Sound selection	00~19	Sound data code No.	05	○	○
12	Upper limiter setting	00~15	Upper limit ratio data code No.	00	○	○
13	Lower limiter setting	00~15	Lower limit ratio data code No.	00	○	○
14	Bias setting	00~15	Bias ratio data code No.	00	○	○
15	Maximum frequency limiter	00	150 Hz or greater operation impossible	00	○	○
		01	150 Hz or greater operation possible			
16	Frequency jump 1 setting	00~60	Setting 1 jump frequency (Hz)	00	–	○
17	Frequency jump 2 setting	00~60	Setting 2 jump frequency (Hz)	00	–	○
18	Frequency jump 3 setting	00~60	Setting 3 jump frequency (Hz)	00	–	○
19	Automatic/manual selection	00	External remote operation by control circuit terminal	03	○	○
		01	Automatic V/F operation		–	○
		02	Automatic torque boost operation		–	○
		03	Front panel manual operation (I/O manual)		○	○
20	Overload alarm signal selection	00~05	Overcurrent set value data code No.	00	–	○
21	Agreement frequency setting	00~60	Setting agreement frequency (Hz)	00	–	○
22	Inverter stop signal selection	00~05	Set frequency data code No.	00	–	○
23	Braking torque switching	00	Standard torque	00	○	○
		01	Strong brake			
		02	DC brake			
24	Current control function selection	00~19	Current control value set data code No.	00	–	○
25	Setting method selection	00	Digital setting from touch panel	00	–	○
		01	Analog setting by external input			
		02	Digital setting by binary code from OPC-04			
		03	*(Digital setting by BCD code from OPC-04)			
26	50~99 Hz base frequency setting	50~99	Setting base frequency (Hz)	50	–	○
27	Remote operation panel option (OPC-09) setting	00	Touch panel remote option not used	00	–	○
		01	Touch panel remote option used			

* Items in ( ) are available upon request.

2.2.2 Miniaturization of structural parts

The number of parts was reduced substantially by making the main circuit section a composite module. The parts were miniaturized and a diecast fan matched to the parts developed and the entire system housed compactly.

2.3 Multiple functions

This series has the following functions so that it can be used in the numerous applications demanded of a general purpose inverter.

2.3.1 Expansion of standard specifications functions

The functions of the inverter can be expanded by combining the function codes and data codes as shown in *Table 2*.

(1) Functions expansion technique

By making the control system a DDC system, operation, judgement, and commands are all controlled by a 16-bit CPU. That is, setting of numerous data with the function signals described previously is easier and more accurate than setting by the conventional multiple selector switches and resistor combination.

(2) Completion of control functions

Current display, current limiting acceleration and electronic thermal protect are possible by a newly developed effective value current detection system.

Four step speed command, JOG (jogging) command, 2-nd acceleration/deceleration time command, overload alarm, etc. are provided as an interface to complete the progrem operation functions.

In addition, the upper and lower limiter, bias setting, and frequency jump functions are performed by software. Real-time control system software that allows automatic V/F and automatic torque boost was also developed. Standard brake, strong brake, and DC brake control systems are used so that the braking characteristic matched to the application and purpose can be selected.

(3) Completion of protection circuits

Since the inverter is used as a general purpose device, the protection circuits are expected to be perfect so that trouble does not occur even in severe use. When a protection circuit operates, the cause is displayed by 7-segment LED.

2.2.3 Expansion of functions by OPC (Option)

Many standard options are available and can be selected according to the purpose and installed directly to the mainframe PC board by one touch.

All option cards have the same dimensions and mounting system and are compactly housed.

2.4 Increased performance

An output current waveform closely approaching sine-wave is obtained and the following high performances are realized by using a frequency band composite control system (patent pending).

(1) Wide frequency control range

With low capacity models of 3.7 kW or less, frequency setting over a wide range, from 0.5 Hz starting frequency to 360 Hz maximum frequency is possible. These models can not only operate ordinary standard motors, but can also drive special ultra-high speed motors.

(2) Frequency control precision

The G5 series can use analog or digital setting. Digital setting, in particular, is advantageous in that temperature drift can be virtually ignored.

(3) Acceleration/deceleration performance

Usually, acceleration/deceleration performance is evaluated in signal steps (frequency increment resolution (ΔHz/Δs)).

Since the resolution of the G5 series is much better than that of the old G2 series, smooth acceleration/deceleration performance is obtained. At the same time, stall control performance is also improved.

3 CIRCUIT COMPOSITION

3.1 Circuit operation

The control circuit block diagram of this series is shown in *Fig. 3*.

3.1.1 Main circuit

The converter (diode rectifier circuit + thyristor module) converts the 3-phase AC commercial power to DC and the inverter (six power transistors) outputs this DC voltage as arbitrary 3-phase AC. In the past, a contactor was used at the surge current protection circuit. However, with the G2 series, reliability is improved by using a semiconductor switch (thyristor).

3.1.2 Control circuit

The CPU section is the range controlled by a 16-bit CPU. This section receives the signals from the touch panel, V/F converter, and protection circuits and performs operation, control, command, waveform generation, etc.

3.1.3 Touch panel

The touch panel is divided into the following two sections with the following functions:

(1) Touch key section

Inverter operation, reset, and function code and data code setting are performed at this section.

(2) LED display section

Frequency display, output current display, and display by tripping are performed at this section.

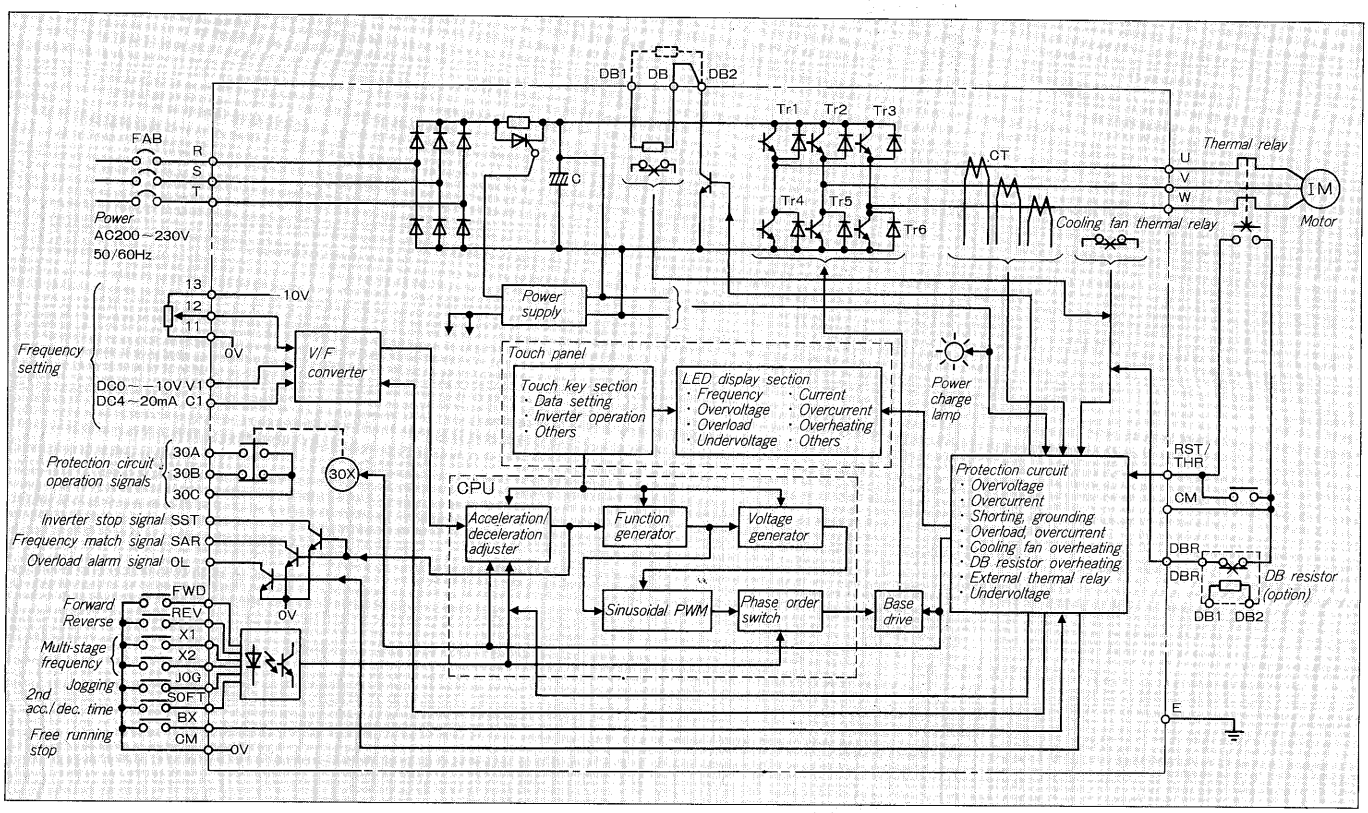
3.1.4 Control power supply

This section is a DC/DC converter with the inverter DC intermediate voltage as its input and constitutes multiple low voltage power supplies. It is a small and low-loss power supply.

3.1.5 Protection circuits and input/output terminals section

This section consists of overvoltage protection (OV), overcurrent protection (OC), inverter overheating (OH), undervoltage (LU) and other inverter protection circuits, frequency setting circuit, output current read circuit, forward command (FWD), reverse command (REV), jogging command (JOG), and other external signal read circuits, and frequency match signal (SAR), inverter stop signal (SST), and overload alarm signal (OL) external

Fig. 3 FVR-G5 control block diagram



output circuits.

3.1.6 Main control circuit

The main control circuit consists of a custom LSI and a base drive circuit. The output waveform is generated by operation by highest priority interrupt by a timer inside the CPU and giving a signal to the base drive circuit through the custom LSI.

4 OPERATING CHARACTERISTICS AND APPLICATION TECHNOLOGY

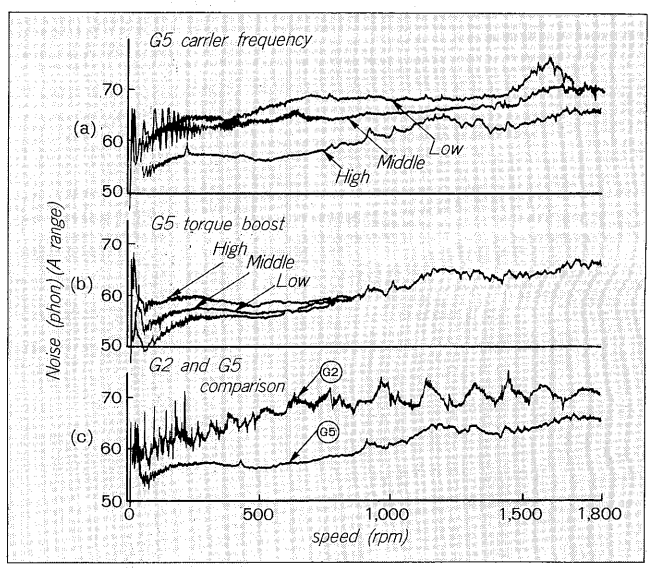
With the popularization of the sinusoidal PWM inverter, noise has become an important problem.

In the past, the carrier frequency was changed in accordance with the inverter output frequency. However, with the FVR-G5 series, the ringing sound produced when the carrier sound is changed is eliminated by making the carrier frequency constant. The FVR-G5 series is also designed so that the carrier frequency can be switched and the motor inherent vibration frequency can be avoided and the tone changed.

Actual noise characteristics are shown in *Fig. 4*. *Figure (a)* shows the carrier frequency dependence, *Fig. (b)* shows the torque boost dependence, and *Fig. (c)* is a comparison to the existing FVR-G2 series.

Next, the multi-stage speed operation function of the expanded function is described. Its wiring diagram and operation modes are shown in *Fig. 5*. Besides allowing free selection of the frequencies memorized from the touch panel beforehand by combining external terminals

Fig. 4 Speed—noise characteristics (0.4 kW standard motor)



X1 and X2, if jogging operation and manual operation by touch panel are included, up to five speeds can be switched by external terminal.

The FVR-G5 series has many other standard functions. The option cards listed in *Table 3* are also available so that it can be used in a wide range of applications. These cards are outlined below.

Fig. 5 Multi-stage speed operation diagram

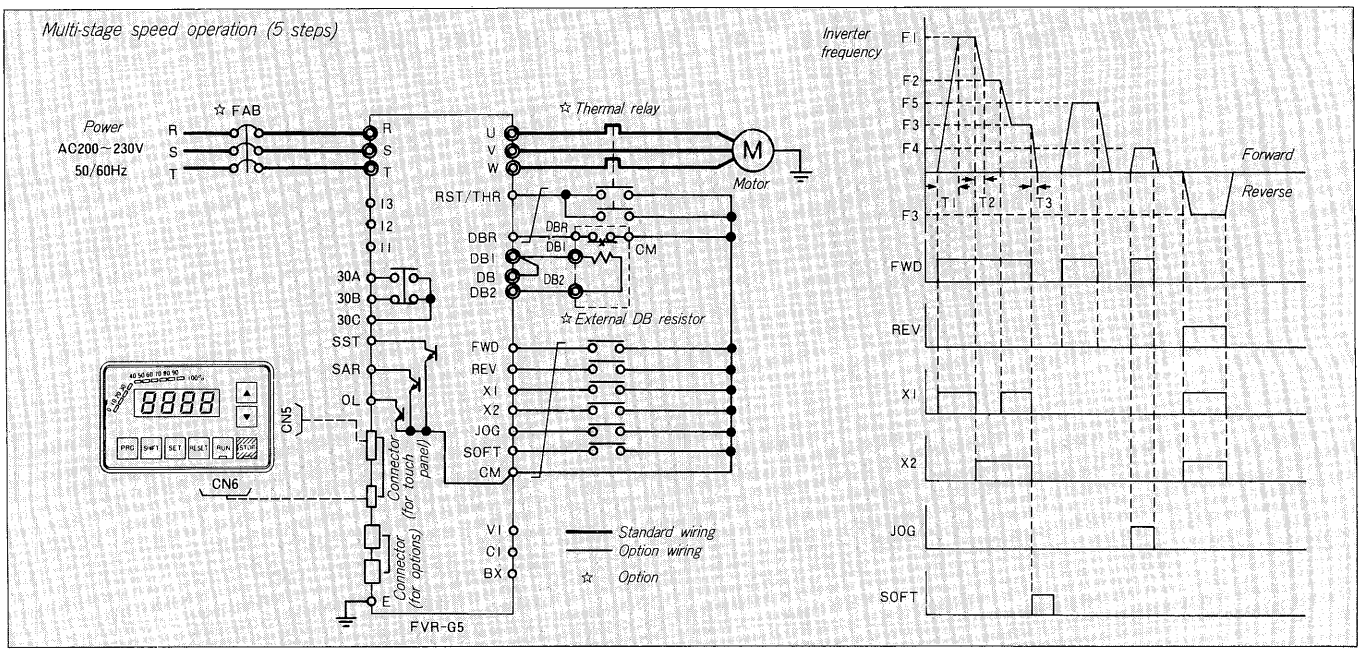


Table 3 Option (OPC) series

Name	Model	Application
Synchronous operation card	OPC-01	Ratio synchronous operation
Relay output card	OPC-02	Outputs undervoltage, inverter stop, speed reached, and overload signals to the outside by relay.
AVR card	OPC-03	Output voltage regulation
Digital interface card	OPC-04	Frequency setting by 8-bit parallel signal
Analog frequency meter drive card	OPC-05	External analog frequency meter drive
TG/PG feedback card	OPC-06	Speed control
Momentary power interruption and commercial power – inverter switching card	OPC-07	Inverter operation at momentary power interruption and recovery
Remote operation touch panel	OPC-09	Remote operation
Remote digital display panel	OPC-10	Remote display

4.1 Synchronous operation card (OPC-01)

This option makes one rotating shaft the reference shaft and the other shaft the subodinate shaft and controls the (θ/rev) rotating shaft angle. Synchronous operation is performed by detecting the angle of the shafts with an encoder mounted to each shaft and controlling the two shafts so that the relative angle of their shafts is always constant. The ratio of the relative angles can also be changed and ratio synchronous operation performed.

4.2 Relay output card (OPC-02)

The standard output signals are open collector, but relay output may be necessary, depending on the facility. This option adds an undervoltage function to the standard functions (inverter stop, frequency match, overload alarm) and generates a relay output (c contacts) as an external signal. This has external signal. This has such merits promoting reduction of the cost of the entire panel instrumentation, shortening the delivery period, etc.

4.3 AVR card (OPC-03)

Usually, the output voltage of a general purpose inverter changes in proportion to the input voltage. The AVR card regulates the output voltage so that a constant voltage is applied to the motor even when the input voltage changes. Generally, vibiation and noise are reduced and other effects are obtained by regulating the voltage.

4.4 Digital interface card (OPC-04)

This option is used to communicate between the inverter and other equipment. Usually, frequency commands are received by analog (DC) voltage or current as signals from the outside. However, when the system is complex (for example, NC machines), the digital interface is effective.

This option has an 8-bit digital input/digital output (DI/DO) and can handle binary, BCD, and other transmission codes. An exterior view of this option is shown in *Fig. 6*.

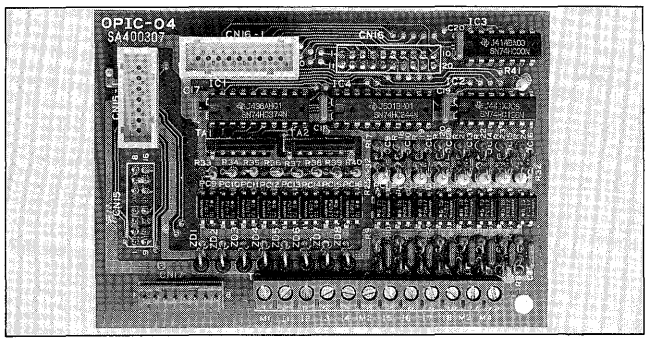
4.5 Analog frequency meter drive card (OPC-05)

The FVR-05 has a 4-digit digital display on the touch panel as standard.

However, display by analog frequency meter of the old system is also demanded and is available as an option.

The output frequency is received digitally from the

Fig. 6 Option OPC-04 exterior view



10217

CPU inside the inverter and is F/V converted and can drive a frequency meter at high precision and fast response.

Since output as digital frequency is also possible, applications other than frequency meter are also possible.

4.6 TG feedback card (OPC-06)

This option is for ASR (automatic speed control) and compensates the motor speed deviation.

A DC tachogenerator, AC tachogenerator (1ϕ, 3ϕ), rotary encoder, etc. can be connected.

4.7 Momentary power interruption and commercial power – inverter switching card (OPC-07)

This is a momentary power interruption restarting and commercial power – inverter switching option.

(1) Momentary power interruption restarting

When a momentary power interruption occurs during operation, the motor slip is forecast, processed, and controlled and motor speed control is performed at recovery.

That is, when a momentary power interruption occurs during operation, the starting frequency corresponding to the load is searched and controlled so that the motor accelerates smoothly when the power recovers.

(2) Commercial power – inverter switching

This system simplifies switching of the motor from commercial power drive to inverter drive.

When the motor is switched from commercial power drive to inverter drive, the starting frequency is searched and controlled according to the load. Switching from inverter drive to commercial power drive is performed directly and the motor is started.

4.8 Remote operation touch panel (OPC-09)

This option is used when the FVR-G5 touch panel is installed remotely and the inverter is operated remotely.

The cable can be extended up to several tens of meters by using OPC-09.

The inverter can be remotely controlled by 4-digit 7-segment display and eight touch switches.

4.9 Remote digital display panel (OPC-10)

This panel does not have the operation functions of OPC-09 and only has a display function.

OPC-09 and OPC-10 can be selected to match the objective.

5 CONCLUSION

The FVR-G5 series of general purpose inverters was introduced above.

To meet the various demands of a wide market, the general purpose inverter, a typical type of variable speed drive device, must be improved and developed further. Fuji Electric will make further efforts toward miniaturization and systemization, including coping with dedication of the inverter, in the future.