White Paper

Current and Voltage Sensing Solutions for Motor Drive Control Using Photocouplers

Yasufumi Kakihana, Senior Staff Engineer, Industrial & Communications Business Div., Renesas Electronics Corp.

Michinari Asai, Senior Manager, Industrial & Communications Business Div., Renesas Electronics Corp.

July 2020

Abstract

The trend of today's industrial motor drive devices (such as robot controllers, AC servos, numerical control (NC) servos, etc.) is towards higher precision control and sensing in harsh environments. In addition, there is the goal of standardizing design during the development of the equipment.

The RV1S9353A meets both of these objectives by using a high input resistance, high precision ΔΣ modulator. The RV1S9353A can be used for both high precision current sensing and for voltage monitoring enabling the common use of components.

Introduction

Due to miniaturization of semiconductor manufacturing equipment, high density mounting of various compact assemblies, mechanization of skilled craftsmanship, etc., motor drive devices such as robot controllers, AC servos, and NC servos used in the equipment require higher precision sensing in a harsh environment and standardizing the design during the development of the equipment.

This white paper proposes Renesas' latest RV1S9353A photocoupler which enables the same product to be used for both high precision current sensing and voltage monitoring.

Issues for Higher Precision

The generic inverter circuit shown in Figure 1 is often used in high voltage industrial automation equipment which requires a low power motor control circuit and reduced power conversion loss.

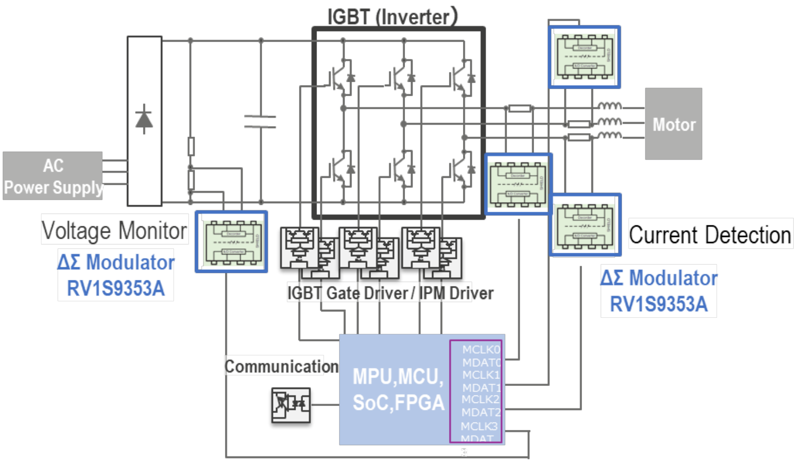

Figure 1: Example of inverter circuit

There are various photocouplers in an inverter circuit. IGBT and IPM drivers are used for communication between the inverter control signal (PWM) from the MCU to power devices such as IGBTs. Isolation amplifiers and ΔΣ modulators are used for motor current sensing and bus line voltage monitoring. Communication couplers are used for electrically isolated communication between the controller (MPU / MCU / SoC / FPGA) and I/O (Input / output) or outside equipment.

The following summarizes the background and issues behind the demands for higher precision motor current sensing and standardization of design.

Background of Higher Precision

The background examples of improving the precision of robot controllers, AC servos, and NC servos are as follows:

- Processing for miniaturization of semiconductor manufacturing equipment and high definition display
- High speed, compact, high density mounting of various assembly equipment
- Mechanization of skilled craftsmanship

For these applications, high precision positioning, high precision machining, and stable speed control in a severe factory environment (high temperature and high noise) are required.

Figure 2 shows the servo control used in robot controllers, AC servos, NC servos, etc. It has a position, speed, and current feedback loop for high precision and high-speed positioning. The current feedback loop controls the force (torque) of motor rotation. The current command value from the controller such as MPU / MCU / SoC / FPGA is compared with the actual motor current value. Based on this, the pulse width of the PWM is adjusted and controlled so that the output waveform closes to the reference waveform (sine wave).

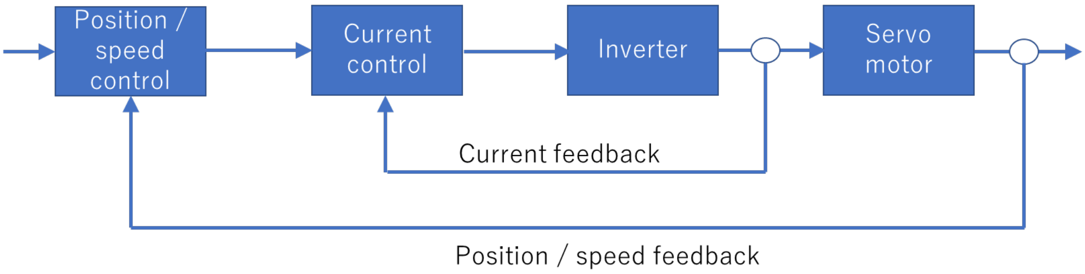

Figure 2: Position, speed, and current feedback loop

For voltage monitor, a circuit as shown in Figure 3 is generally used. Resistors (R1, R2) divide the high voltage. R2 should be selected to set the input voltage (200mV) of the ΔΣ modulator or the isolation amplifier. Here, when R1 >> R2 and the input resistance of the Σ modulator or the isolation amplifier is Rin, the detection error is R2 / (R2 + Rin). Therefore, when the input resistance Rin of the ΔΣ modulator is sufficiently large compared to the voltage dividing resistor R2, the detection error can be reduced, and the detection can be performed with high precision.

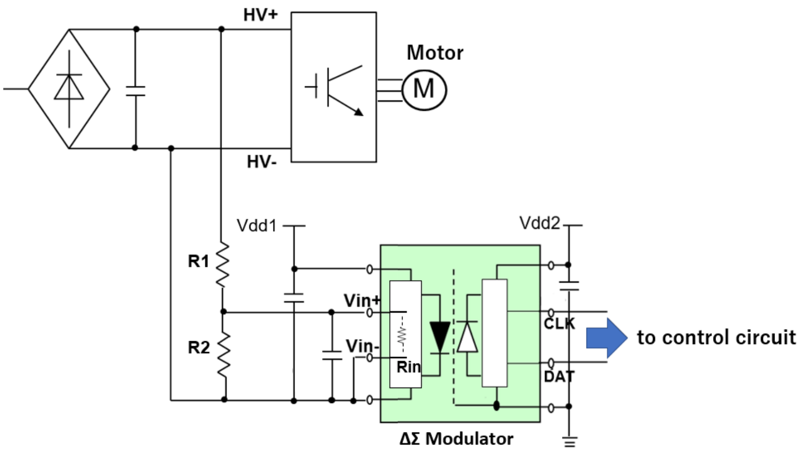

Figure 3: Example of voltage monitor circuit

Standardizing the Design (Common Use of Component)

It is important to focus on total cost reduction from development to mass production, instead of focusing only on product (photocoupler) costs. For example, standardization of components can reduce design and evaluation requirements, component reliability test and certification time, and component management once in mass production.

In many cases, the current sensing circuit uses relatively accurate ΔΣ modulators, and the voltage monitor circuit uses different analog isolation amplifiers with relatively low precision and high input resistance. This situation requires separate design, evaluation, and temperature characterization, etc. If the same component can be used for both applications, the development period can be shortened and lead to total cost reduction.

Safety Standards

Safety cannot be compromised in the search for cost reduction. Photocouplers meeting safety standards UL1577, EN60747-5-5, and the recently changed UL61800-5-1 for motor drives, are essential for industrial equipment applications.

Renesas Photocoupler – RV1S9353A

Renesas' RV1S9353A is an optically coupled ΔΣ modulator which has the characteristics shown in Table 1 and provides high precision and standardization of design, while maintaining the industry standard noise immunity CMR (Common Mode noise Rejection).

The RV1S9353A can be used for both motor phase current sensing with its high SNR, low offset temperature drift and voltage drift, and for voltage monitoring with its high input resistance.

Part Number*1)	Package		Absolute Maximum Ratings		Electrical Characteristics								
	Code	Outer Creepage [mm]	Isolation Voltage [Vr.m.s.]	Ta Max [℃]	Output clock frequency typ [MHz]	Gain error Max [%]	Gain Temp. Drift typ [ppm/℃]	Offset Temp. Drift typ [uV/℃]	SNR typ [dB]	CMR typ [kV/us]	VDD1 /VDD2 [V]	Input resistance typ [kΩ]
RV1S9353A CCSP-120C	SDIP8	8	5000	110	10	0.5	30	0.2	85	25	4.5~5.5 /3~5.5	500

Table 1: RV1S9353A Characteristics outline

As shown in Figure 4, the package is an 8-pin SDIP with a 1.27mm pitch, creepage and clearance distance of 8mm, and isolation voltage of 5kVr.m.s. Despite its small size, RV1S9353A is suitable for reinforced insulation of 200V and 400V AC motor drive devices.

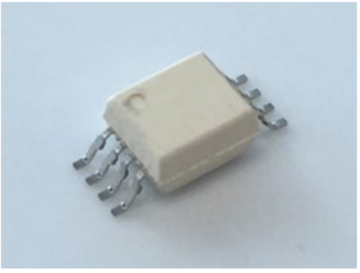

Figure 4: RV1S9353A SDIP8 package

Higher Precision

For high precision current sensing, the RV1S9353A has an optimized second order ΔΣAD converter circuit and the miniaturized wafer process leading to improved effective resolution and offset voltage temperature drift that is difficult to correct by equipment. Figure 5 shows a comparison with the conventional product PS9352A. The RV1S9353A has a high effective resolution of SNR = 85dB (typ.), ENOB = 13.8bits (typ.) and Input offset voltage temperature drift 0.2uV / ° C (typ.), and Reference voltage temperature drift 30ppm / ° C (typ.), which reduces the effect of temperature changes on equipment precision. The RV1S9353A has a 200mV input voltage range and is suitable for current sensing up to about 150A when combined with the appropriate shunt resistor.

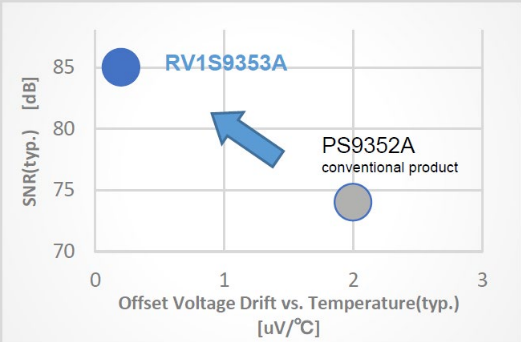

Figure 5: Comparison of conventional product PS9352A and new RV1S9353A

In voltage monitoring applications, the input resistance of the RV1S9353A is 500 kΩ typ., which is a factor of 10 larger than the input resistance of a general current sensing ΔΣ modulator (typically several tens of kΩ), which leads to a significant reduction in the detection error (R2 / (R2 + Rin) in Fig. 3).

Standardizing the Design (Common Use of Component)

The RV1S9353A is the world's only high precision ΔΣ modulator with a high input resistance (typ. 500 kΩ) for current sensing. As described in the previous section, the RV1S9353A can be used for both current sensing and voltage monitoring allowing components to be shared. Furthermore, the use of the RV1S9353A for voltage monitoring eliminates the need for the complex analog design required by the conventional analog isolation amplifiers. This is because the filter part becomes a digital filter for which different characteristics can be realized even with the same components and circuit, and the filter characteristics are not affected by variations in components or temperature (Table 2).

	Analog filter	Digital filter
Features	･Filter with different characteristic requires different components and circuit ･Filter characteristics are affected by temperature drift ･Filter precision is affected by component precision (variation) ･Higher order filters are complex and have many components	･Filters with different characteristics are possible with the same components and circuit ･Filter characteristics are not affected by temperature drift ･Filter precision is not affected by component precision (variation) ･Higher order filters are easier than analog

Table 2: Comparison of analog and digital filters

Safety Standards

The cross-sectional structure of the RV1S9353A is shown in Figure 6. A facing type structure using silicone and a polyimide film is adopted, and the LED and the photo detector IC are positioned to ensure an insulation distance of 400 um. This is different from the on-chip structure of digital isolators which typically have an insulation distance of about 10um and a longer distance between input and output. The RV1S9353A can secure a voltage margin for the isolation voltage rating.

Also, when considering the end of life, a photocoupler will be in the open mode due to the decrease in the brightness of the LED, while the digital isolator will be in the short mode due to oxide or polyimide film break down, which may cause an electric shock accident. Photocouplers have been used as isolation devices for over 40 years in many applications and contribute to an improvement of the system safety.

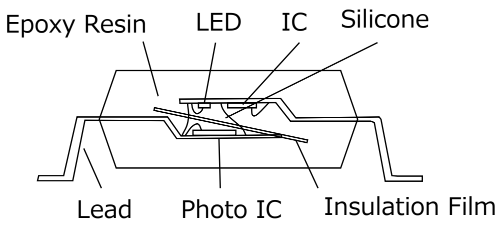

Figure 6: Cross section views of RV1S9353A

The RV1S9353A has a very strict standard double protection as required in UL1577 and also supports DIN EN 60747-5-5 (VDE 0884-5) as an option. In addition, although the standard of motor drive devices has shifted from UL508C to UL61800-5-1 and the creepage and the clearance distance have changed, the RV1S9353A can support reinforced insulation of AC 200V and AC 400V equipment.

Conclusion

In the harsh environments of motor drive devices such as robot controllers, AC servos, and NC servos, the ΔΣ modulator RV1S9353A from Renesas Electronics provides solutions to the conflicting issues of high precision current sensing and voltage monitor and common use of component.

Additional Resources

Renesas Electronics photocoupler web site:
https://www.renesas.com/products/optoelectronics.html

Renesas Electronics photocoupler catalog:
https://www.renesas.com/us/en/doc/products/opt/r08cp0001ej0200-photocoupler.pdf