Adaptive load regulation enables cool designs for analogue outputs

By Jürgen Schemel, Field Applications Engineer, ADI

Today's typical programmable logic controller (PLC) contains a multitude of analogue and digital outputs for the control and monitoring of industrial and production processes. Modularisation is widespread and, with respect to inputs and outputs (I/Os), covers the basic functions of analogue I/Os and digital I/Os. The analogue output presents a particular challenge because, as shown in Figure 1, a set value must be driven actively and with high accuracy under many different load conditions. The active driver stage is important here; losses should be kept as small as possible.

The factors to be considered are as follows:

- Connected load
- Maximum allowable ambient and internal module temperatures
- Number of channels and size of the module
- Galvanically-isolated interface
- Accuracy.

In process automation, there is often an additional requirement for a galvanic barrier between individual output channels. Besides that, there are still other conditions such as channel-based diagnostics or support of HART signals. Robustness and fault tolerance are also prerequisites.

Thanks to developments in semiconductors and continuously improved mixed-signal processes, very small circuits with high integration densities are possible. The function of an analogue output channel can be completely integrated in an IC. Thus, on 5mm × 5mm, the AD5758 part from Analog Devices (ADI) unites the basic function of a DAC and a driver as well as several other analogue and logic functions such as an ADC for diagnostics, intelligent power management, a voltage reference, a fault switch against reverse and overvoltages, a register for calibration data, and the SPI communication interface.

The AD5758 (Figure 2) covers all common output ranges used in automation: unipolar 0-10V/0-20mA, bipolar ±10V/±20mA, and all subranges such as the 4-20mA used in process automation. Each setting offers a 20% overrange. The values are output with a 16-bit resolution.

Power loss minimisation

What makes the AD5758 particularly suitable for temperature- and space-critical applications? Losses occur mainly in the power section with the DC-to-DC converter and the output driver stage. This is where intelligent power management comes into play. The AD5758 features adaptive load regulation or dynamic power control (DPC). DPC is active in current output mode and controls the voltage at the driver stage needed to drive a specific load. Depending on the operating condition, the load voltage for current output ($I \times R_{LOAD}$) only makes up a fraction of the supply voltage. The difference with respect to the supply voltage must previously be dissipated in the series transistor in the form of a power loss. The DPC now regulates the driver voltage to a few volts above the actual required load voltage (headroom for output transistor) and thus provides for minimal losses. Efficient

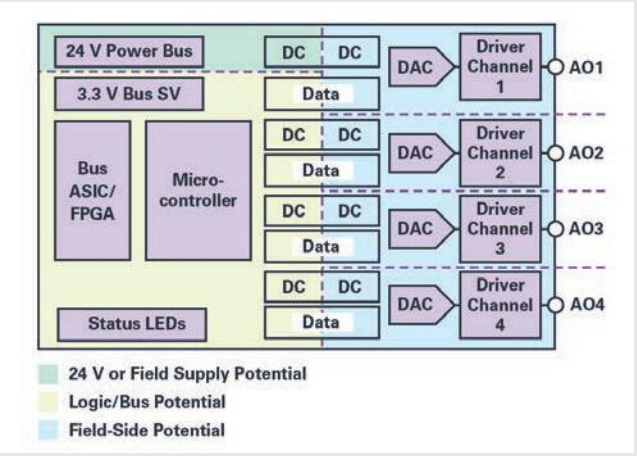

Figure 1: Block diagram of an isolated analogue output

adjustment of the voltage in this way is only possible via a switching regulator, which is already integrated in the AD5758 and is automatically controlled based on the load. Even if additional losses arise in the switching regulator and in the upstream power supply, the overall power loss reduction is very effective, especially for small load resistances. It makes smaller designs possible, and the board stays cool.

Derating sets tight limits

Derating is defined as a reduction in performance under defined boundary conditions, similar to the safe operating area (SOA) consideration in power semiconductors. Because of the previously mentioned power loss and associated cooling problems, tight thermal limits are imposed on the output modules without DPC. Today, two or four channels on a credit card-sized module are common. The modules are usually specified for ambient temperatures up to 60°C. Under these environmental conditions, however, not all four channels can drive very small loads because with four channels

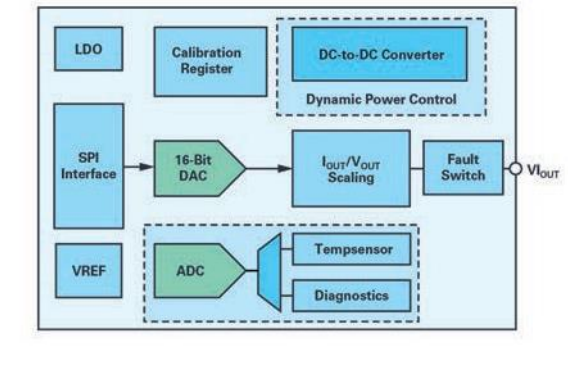

Figure 2: Block diagram of the AD5758

without DPC, the power loss in the module can reach 3W and the heat generated can quickly push the components to their limits. With thermal derating, the module manufacturer enables use of only one or two of the available four channels at high ambient temperatures, drastically worsening the usability and channel costs.

Thanks to its adaptive regulation, the AD5758 has a power loss that only slightly depends on the load resistance and always remains at < 250mW for loads of 0-1kΩ. Thus, depending on the design of the output module, it may be possible for eight isolated channels to be realised at < 2W. The 5mm × 5mm LFCSP with its thermal resistance from junction to ambient Θ_{JA} of 46K/W increases the ambient temperature by less than 10°C at a power loss of 200mW. The AD5758 was specified for ambient temperatures of up to 115°C, which offers a lot of headroom for multichannel modules without derating.

Optimised power supply

The supply voltages have different requirements:

- **Logic voltage:** Apart from the (operating mode dependent unipolar or bipolar) driver supply, the AD5758 output IC requires a 3.3V logic voltage for the internal blocks. This can be generated with the on-chip LDO regulator; however, for optimal efficiency and lower power loss, a switching regulator is recommended.
- **Isolated driver supply:** For safety reasons, the PLC bus is always galvanically-isolated from the I/O modules. Figure 1 shows this isolation with colour coding for the three different potentials of logic (bus) side, voltage supply and field-side output.

Because these three sections are also often spatially separated on the board – the outputs are positioned toward the front connector terminals, with the backplane bus at the back – integration of the isolation, power supply and output driver on a single chip would not make sense.

The power management unit ADP1031 (Figure 3) performs all functions and, together with the AD5758, enables development of isolated output modules with minimal space requirements and power loss (Figure 4).

The ADP1031 integrates four blocks on 9mm × 7mm:

- Flyback converter for generation of an isolated positive supply voltage V_{POS}
- Inverter for the negative supply for bipolar outputs V_{NEG}
- Step-down converter for supply of the AD5758 logic circuits with V_{LOG}
- Isolated SPI data interface with additional GPIO.

The advantage of the flyback converter is its high efficiency; only a small 1:1 transformer is needed. The flyback converter generates the isolated driver voltage up to 28V in the first stage. The inverter and the step-down converter are derived from this and share the same ground potential.

During the design of the power management unit, special emphasis was placed on electromagnetic compatibility (EMC) and robustness. For example, the output voltages are phase-shifted and the slew rate of the flyback controller is adjustable. Soft start, overvoltage protection and current limitation for all three voltages are also added for good measure.

The isolated SPI interface is based on ADI's proven iCoupler technology and transfers all control signals required for operation. Distinction is thereby made between a high-speed path (four channels) for the data and a slower path (three channels multiplexed) for control of GPIO. Possible applications are synchronous activation of the outputs in multichannel modules or across several modules via a common control signal, reading-back an error flag, or triggering a safety shutdown.

The combination of the AD5758 and the ADP1031 offers complete functionality for an isolated analogue output on two chips. At approximately 13mm × 25mm, the channel space requirement is minimal – half the size of today's solutions.

In addition to the space savings, the integration of the key functions offers a simpler layout, easy separation of potentials and significantly lower hardware costs. The 8-channel demo design from ADI just uses one board with six layers and measures 77mm × 86mm.

Advantages summary

- Smaller modules and more channels per module through optimised power loss
- No derating and higher allowable ambient temperatures
- Reduced costs due to lower hardware efforts
- Easy scalability of multichannel modules
- Robust design with extended diagnostics capabilities. EW

Analog Devices UK
Tel: 01932 358530 | www.analog.com

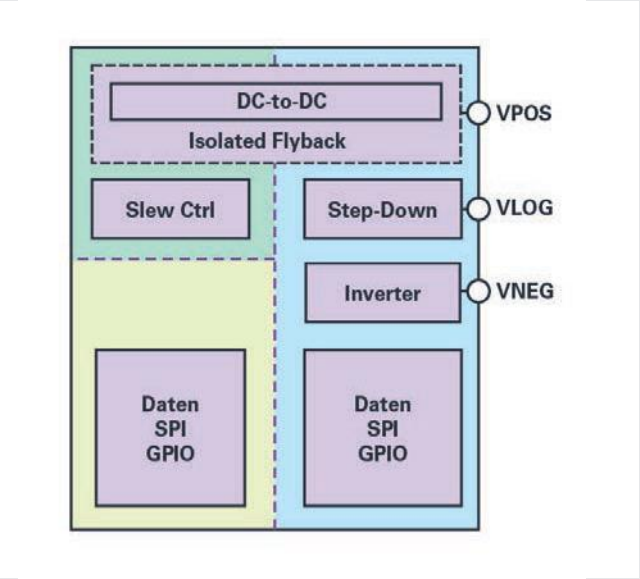

Figure 3: Power management unit ADP1031

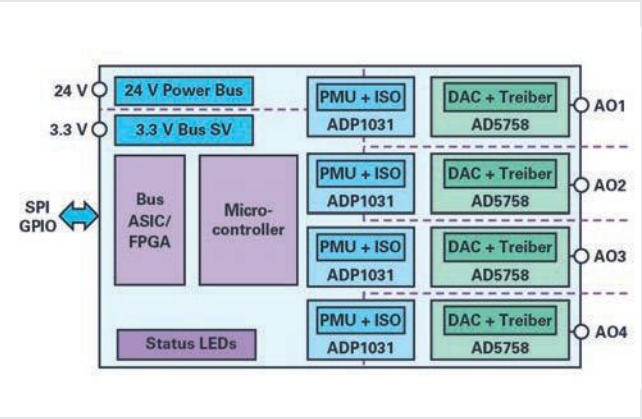

Figure 4: Complete 4-channel analogue output with the ADP1031 and AD5758