

## White Paper

# How to Reduce Size, Weight and Power of Satellite Command and Telemetry Subsystems

## Introduction

By 2017, there were nearly 1,400 satellites in orbit, serving both military and commercial customers. Their missions span a wide range of functions including reconnaissance, surveillance, imaging, signal intelligence, meteorology, navigation, television, and voice communications. With every new mission, customers increasingly want more functionality, which requires larger satellite payloads, and that forces manufacturers to increase the size, weight and power (SWaP) of their satellite command and telemetry systems.

This white paper discusses how using the ISL72813SEH 32-channel driver IC and the ISL71841SEH multiplexer simplifies the design of a next-generation satellite command and telemetry subsystem. Examining these components reveals that they reduce footprint size by up to 50%, while doubling the number of telemetry data inputs and command outputs. Also, we'll discuss the basic operation of the command output circuit, and its role in the overall telemetry system. And we'll compare the 32-channel driver IC to an 8-channel device, and show how it significantly decreases circuit size.

Figure 1 shows a block diagram for a next-generation satellite command and telemetry subsystem that typically has hundreds of telemetry inputs and command outputs. The 32-channel driver array controls the relays and solenoids used to turn on and off the propulsion system thrusters, to change orbital altitude, configure payload waveguide and coax switches, or turn on a motor to tilt the solar panels.

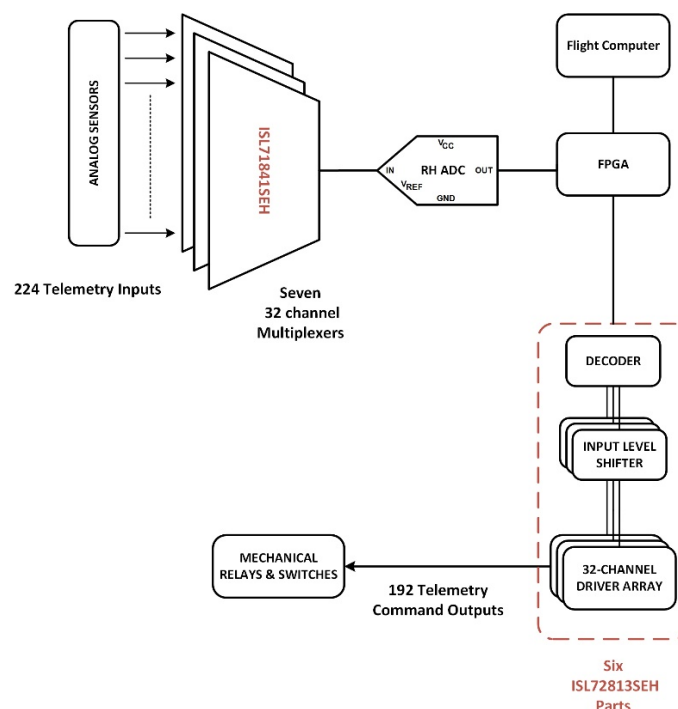
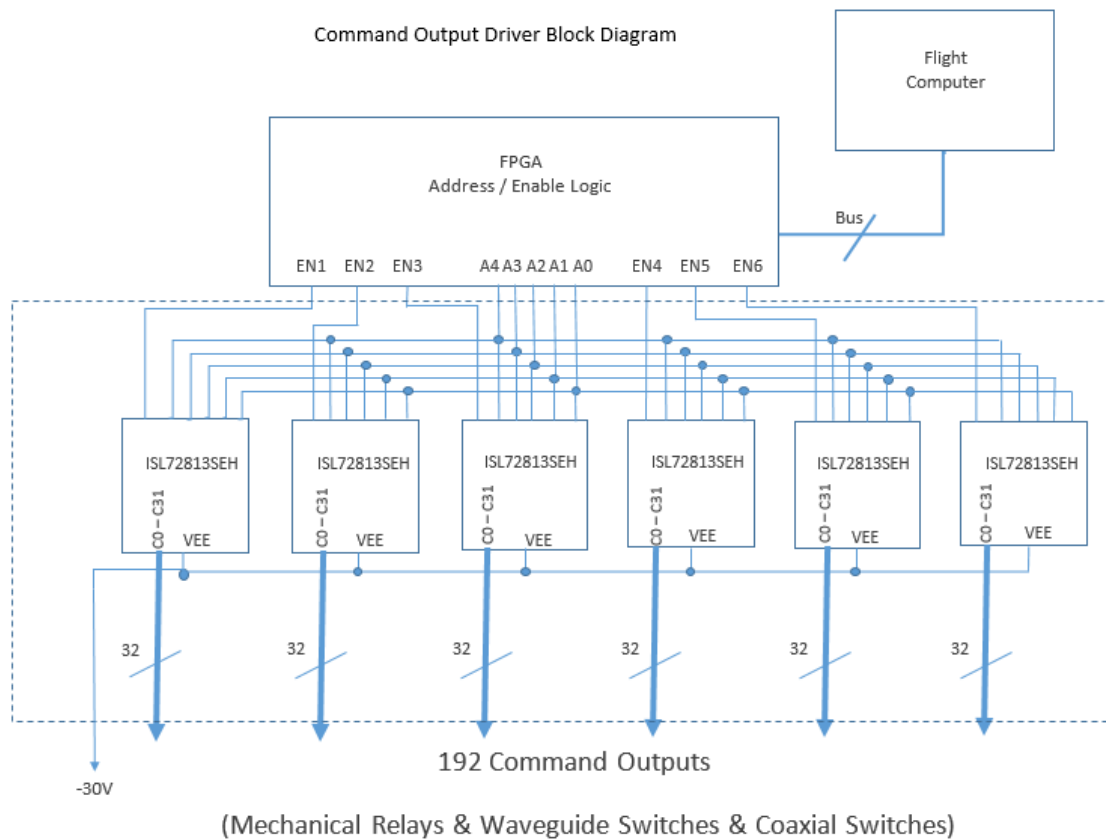


Figure 1. Block diagram of next-generation command and telemetry subsystems

The ISL72813SEH 32-channel driver circuit IC drives the coils of relays, waveguide and coaxial switches that can require up to 500mA of current and -28V across their coils. Relays, waveguide switches, and coaxial switches are common components used in spacecraft and satellite command subsystems. The logic inputs to the ISL72813SEH are TTL/CMOS compatible allowing easy interface to CPUs, FPGAs, or  $\mu$ Processors.

## Operation of the Control Command Output Circuit

Figure 2 shows the block diagram of the satellite’s command output circuit.



**Figure 2. Block diagram of command output circuit**

The circuit consists of six ISL72813SEH driver ICs that allows for 192 command outputs. Each output goes to the coil of either a relay or a solenoid in a waveguide or coaxial switch that require -28Vdc across their coils to activate their main circuit. A relay coil draws <100mA of current while a waveguide/coaxial solenoid can draw up to 500mA current. The commands from these devices are used to control the communications payload and other subsystems in the spacecraft.

Power for the relay and switch coils is provided by a -30V dc power source connected at the common-emitter (VEE) of the six drivers. The -30V dc source provides up to 500mA to power the ISL72813SEH outputs.

An ISL72813SEH device has five logic inputs (A0 – A4) to select one of the 32 driver channels and an enable pin that can be used to disable all of the 32 channels when driven low. Each of the (A0 – A4) logic pins of the six ISL72813SEH drivers are connected in parallel, as shown in Figure 2, and connected to five of the FPGAs logic outputs. Each enable pin of the six drivers go to a separate FPGA output logic pin. Only one

channel of an ISL72813SEH's 32 channels can be activated at a time. However, it is possible to turn on up to six channels simultaneously by driving all six of the enable pins high.

When a specific driver channel is commanded by the flight computer to be activated, the FPGA will apply the appropriate logic signals to select and enable the channel. It then holds the enable pin high for a specific time, which generates a -28V at the output of the selected channel to momentarily drive the channel's load.

The application only requires 12 logic outputs from the FPGA to control the 192 command outputs. The logic inputs of the six ISL72813SEH devices responds to TTL logic levels and the FPGA drives them directly with 3.3V or 5V logic.

## Advantages of the New Design

Older designs use discrete current driver arrays to build the command output subsystem. A single driver array IC contains at most eight Darlington current drivers in a 20-lead LCC package. To use the driver array ICs in an application requires an external blocking diode at each of the Darlington inputs and 16 level shifting circuits shared between Darlington inputs. The diodes at the input side of the Darlington drivers are required due to a leakage path inside the driver. The level shifting circuits allow 5V logic to control the driver array ICs when their ground is connected to -30V. Each level shifting circuit consisted of three resistors and one transistor.

Figure 3 shows the components and circuitry replaced by one ISL72813SEH part, which replaced four discrete current driver array ICs. Also eliminated were 32 blocking diodes and 16 level shifting circuits, which consisted of 48 resistors, 16 transistors, and a pair of decoder ICs that are used to select one of the 16 level shifting circuits. Note that for a circuit card with 192 command outputs, six ISL72813SEH parts would replace 24 discrete driver array parts, 192 blocking diodes, two 3 to 8 decoders, and 16 level shifting circuits, which includes 48 resistors and 16 transistors. The new output design offers better than a 2:1 footprint reduction over the old design.

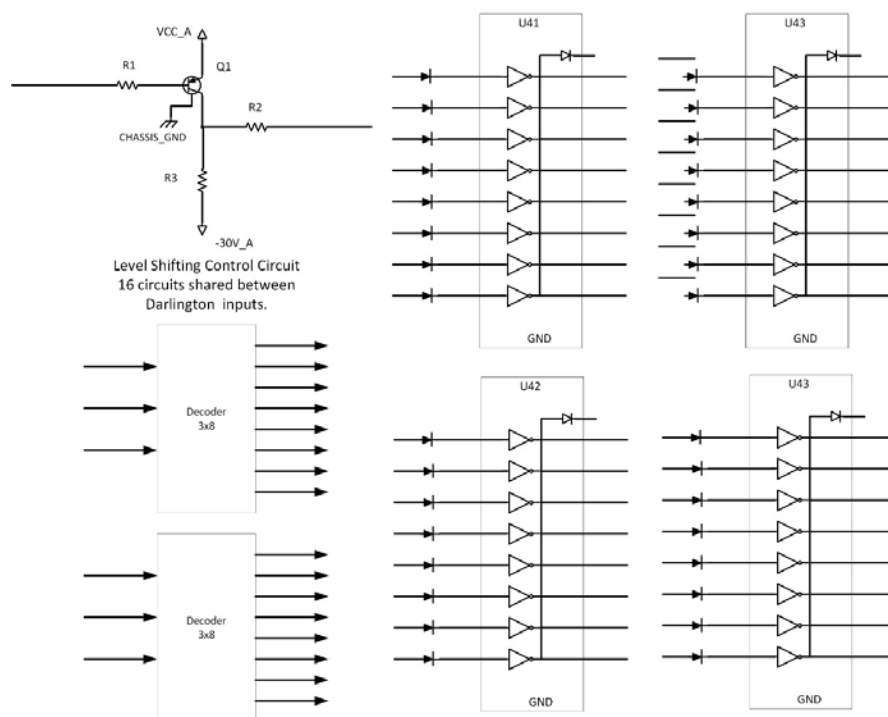


Figure 3. Components replaced by one ISL72813SEH part

Figure 4 shows the ISL72813SEH functional block diagram. It is a radiation hardened 32-channel high-voltage, high current driver circuit with integrated level shifter and 5-bit to 32-bit logic decoder. The decoder selects one of the 32 available driver channels, and its enable pin can disable all 32 channels. The device integrates 32 high current complementary Darlington drivers that feature high-voltage, common emitter, and open-collector outputs with a 42V breakdown voltage and peak current rating of 600mA. In addition to the 32 driver channels and the level shifting circuitry to reference the output base of a selected channel to a negative voltage, the ISL72813SEH's six logic pins control the 32 drivers, which eliminates 4:16 decoder and 16 level shifters used in the old design.

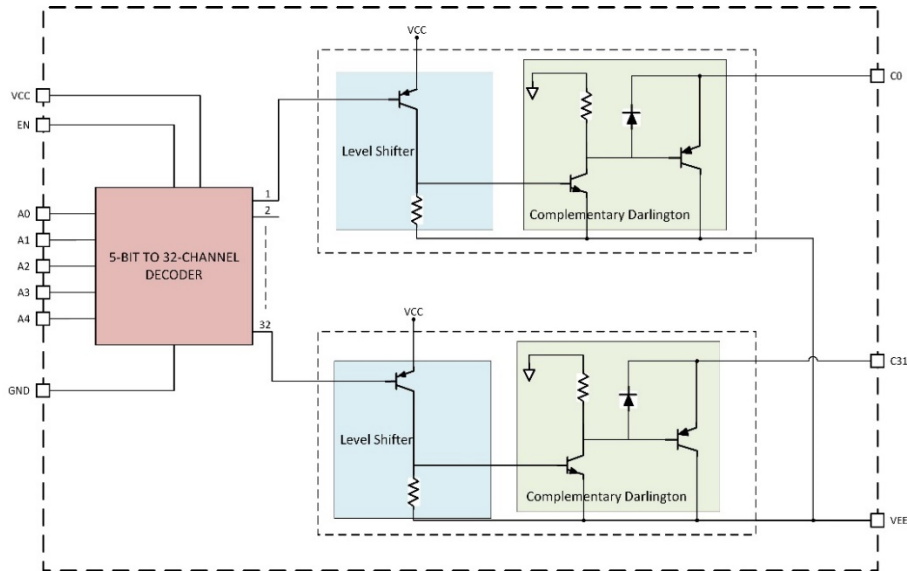


Figure 4. ISL72813SEH functional block diagram

## Benefits of New Telemetry System Design

- One ISL72813SEH replaces four discrete current driver array ICs, 32 blocking diodes, address decoding and level shifting control circuits for more than a 2:1 footprint reduction.
- Higher integration with the new Intersil devices enables a 2x increase in the number of telemetry inputs and command outputs. The reduced size of the command and telemetry subsystem improves the ratio of bus equipment to payload equipment on a spacecraft. This improves the satellite performance, since the payload is the source of revenue for a communication satellite.
- The ISL72813SEH at 500mA has a VCE(SAT) voltage limit of 1.45V vs. the discrete IC Darlington driver's limit of 2.1V @ 500mA. The lower VCE(SAT) rating of the ISL72813SEH reduces the overhead voltage to drive the coil load and minimizes power dissipation by almost 30%.
- The ISL72813SEH's integrated decoder simplifies the logic control circuitry required by the old design built with 1-input to 1-output driver arrays. The ISL72813SEH can be controlled by 3.3V or 5V logic levels.
- The ISL72813SEH has very low OFF channel leakage current of 40nA max vs. 100µA for the Darlington driver. This eliminates voltage glitches that can be present on lightly-loaded Darlington outputs of the old design.
- The ISL72813SEH drives the relay and switch coils that typically require -28Vdc commonly used in spacecraft and satellite applications. The device's common emitter requires a negative voltage to operate properly and can operate with a negative supply voltage up to -42V terrestrial and -33V in the

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space environment. The discrete current drivers in the old design were primarily designed to operate with a positive voltage. Connecting its ground to -30Vdc required additional discrete components such as blocking diodes and a level shifting circuit at the driver inputs.

- The ISL72813SEH enable function allow multiple devices to be easily cascaded together to achieve the desired number of command outputs.

## Radiation Hardened for Mission Assurance

Space radiation effects on electronic devices are an important system design consideration. They can cause problems ranging from operational malfunctions to severe physical damage to the devices and possibly a catastrophic mission failure.

ICs are susceptible to two types of space radiation effects caused by electrons and protons trapped in the terrestrial magnetic field: total ionizing dose (TID) and single-event effects (SEE). TID effects are the result of accumulated exposure to ionizing radiation. SEE are the result of a single high-energy particle that strikes the device.

The total dose radiation (TID) exposure is measured in rads. The term rad (radiation-absorbed dose) quantifies the total radiation exposure of a material. One rad(Si) is equal to  $10 \times 10^{-6}$  W of energy absorbed per gram of silicon. The total dose radiation threshold of a device is the minimum level of rad(Si) that will cause device failure. Typical commercial devices can survive around 5krads before functional failure occurs.

SEE events are significantly more hazardous to the satellite. The intense proton and heavy ion environment encountered in space applications can cause a variety of SEE in electronic circuitry, including single-event upset (SEU), single-event transient (SET), single-event functional interrupt (SEFI), single-event gate rupture (SEGR) and single-event burnout (SEB). SEE can lead to system-level performance issues including disruption, degradation, and destruction. For predictable and reliable space system operation, individual electronic components should be characterized to determine their SEE response.

TID testing on the ISL72813SEH was done to a high dose rate of 100krad(Si) at 50rad(Si)/s to 300rad(Si)/s and to a low dose rate of 50krad(Si) at 0.01rad(Si)/s under biased and grounded conditions. These tests were followed by a biased anneal at 100°C for 168 hours as outlined in MIL-STD-883 Test Method 1019. No rejects to SMD parametric limits were encountered. All parameters showed excellent stability over irradiation, with no observed dose rate or bias sensitivity. The ISL72813SEH device has a high dose rate guarantee of 100krads and a low dose rate guarantee of 50krads.

The SEE testing of the ISL72813SEH part was intended to find the limits of the VCC and VEE supply voltages for avoiding destructive SEB at a linear energy transfer (LET) of 86 MeV • cm<sup>2</sup>/mg. In addition, testing was done to look for significant SETs impacting the driver channel activity at LET of 86 MeV • cm<sup>2</sup>/mg and 28 MeV • cm<sup>2</sup>/mg. Single-event latch-up (SEL) was not an explicit consideration since the part is manufactured in a dielectrically isolated process.

## Summary of SEE Testing Results

- No SEL: Manufactured on Intersil's proprietary PR40 SOI process ensures single-event latch-up immunity
- No SEB for ions with LET ≤ 86 MeV • cm<sup>2</sup>/mg with VCC = 6.5V and VEE = -33V with a case temperature of +125°C
- SET of ≤ -2V VCx of an off switch detected for LET = 28 MeV • cm<sup>2</sup>/mg (Fluence 2 x 10<sup>6</sup> ion/ cm<sup>2</sup>) to a cross section of 5.10x10<sup>-5</sup> cm<sup>2</sup>
- SET of ≤ -2V VCx of an off switch detected for LET = 86 MeV • cm<sup>2</sup>/mg (Fluence 1 x 10<sup>6</sup> ion/ cm<sup>2</sup>) to a cross section of 1.22x10<sup>-4</sup> cm<sup>2</sup>

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- SET error rate estimate for a GEO orbit of  $7.093 \times 10^{-5}$  events/device/day (approximately 1 event/device every 40 years)

## Conclusion

The ISL72813SEH is the industry's first radiation hardened, high voltage, high-current driver circuit to integrate the decoder, level shifter and 32-channel driver array in a single monolithic IC, allowing satellite manufacturers to reduce command and telemetry subsystem solution size by up to 50%. The device offers a 4x higher density channel count compared to the nearest competitor and the integration of the decoder and level shifter circuitry eliminates many peripheral discrete components.

The device is specifically designed to drive relays, waveguide switches and coaxial switches that are commonly used in communications spacecraft. The ISL72813SEH device allows satellite and spacecraft manufacturers to reduce the size of their command and telemetry subsystems by reducing mass, cost, and power, also known as SWaP. This allows customers to accommodate increase payload size by reducing the footprint and mass of bus components. Since the payload generates the revenue from the satellite this is a win/win improvement for the satellite manufacturer and their customers.

## Next Steps

- [Learn more about the ISL72813SEH](#)
- [Download the datasheet](#)
- [Download the SEE and ELDRS TID Reports](#)

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