Application Report

PowerPath Management Solution for BTS Antenna Sharing Hub Using TPS2660 eFuse

TEXAS INSTRUMENTS

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ABSTRACT

With the advent of 5G communication, mobile networks are becoming denser to provide better coverage and more capacity. To speed up network construction and improve cost at the early stage of network development, telecommunication infrastructure sharing, such as multi-port antenna sharing, is also becoming more popular. In addition, antenna line devices (ALDs) need to upgrade from meeting the requirements of the AISG v2.0 to AISG v3.0 as the antenna interface standard evolves.

The traditional powerpath management solution of Antenna Sharing Hub (ASH, one kind of ALD) uses ORing diodes to connect multi-operator' power supplies in parallel. With this method, only the highest input voltages are passed to the output and others are ignored, no matter which operator requests to actuate the antenna Remote Electrical Tilt (RET). The problem is that the operator with the highest input voltage may take on all electricity bills although in an antenna sharing scenario of multi-operator.

Comparing to 2G or 4G, a 5G antenna needs to adjust frequently in real time due to massive MIMO and beamforming techniques. Operators need to separately settle electricity bills based on their actual needs rather than simply split the bill. In addition, ORing diodes cannot provide inrush current control which is mandatory in AISG v3.0. And discrete P-MOSFET inrush current control solution is bulky and expensive. This application note provides an improved integrated solution for antenna sharing hub using TI device TPS2660x eFuse to solve above issues and meet the requirements of AISG v3.0 specification.

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1 Introduction

In modern mobile communication system, the tilt of Base Transceiver Station (BTS) Antenna often needs to be remotely adjusted through Remote Control Unit (RCU) or integrated Remote Control Unit (iRCU) with the help of integrated stepper motor, to focus the antenna beam in a specific area to achieve spatial isolation and reduce the interference of frequency reuse between cells. This system is called Remote Electrical Tilt (RET) Antenna system. The power and control signal from BTS to RCU/iRCU is implemented by the AISG interface. iRCU means it is integrated into the antenna.

1.1 Antenna Deployment

In the past, all operators have their own BTS and antennas deployed separated. This could waste a lot of money and space for telecommunication infrastructure construction. Now in many countries, operators are required to share the network infrastructures, especially multi-port antennas, to save space and reduce damage to the environment. The communication industry also reaches a consensus that telecommunication infrastructure sharing will become more popular, to speed up network construction at the early stage of network development, improve cost savings and focus more on customer services.

The multi-port antenna typically has a single AISG interface allowing RET control by only one operator. To achieve multi-port antenna sharing with different RET control signals coming from two or more operators, an Antenna Sharing Hub (ASH), also called Site Sharing Adapter (SSA), is required to be deployed between operators and antennas to interconnect different RET control signals. By this way, RCU/iRCU of multi-port antennas is shared across multiple operators (commonly up to three or six operators).

Normally three antennas with each one covering 120° sector needs to be deployed in different directions to cover omnidirection. Figure 1-1 shows the traditional singleband antenna deployment for single mode (2G/4G) of three operators. And each operator may need to have its own antenna tower to deploy a lot of antennas, especially when needs to support multiple modes (2G, 4G, and 5G). Figure 1-2 shows the new shared multi-port/ multi-band antenna deployment for single mode (2G/4G) of three operators using a 3-port ASH. Even if needs to support multiple modes (2G, 4G, and 5G), All operators can share one antenna tower, with antennas for different modes being deployed in vertical space. In Figure 1-2, antenna feeder cables are not presented for simplification and iRCUs are connected in daisy chain.

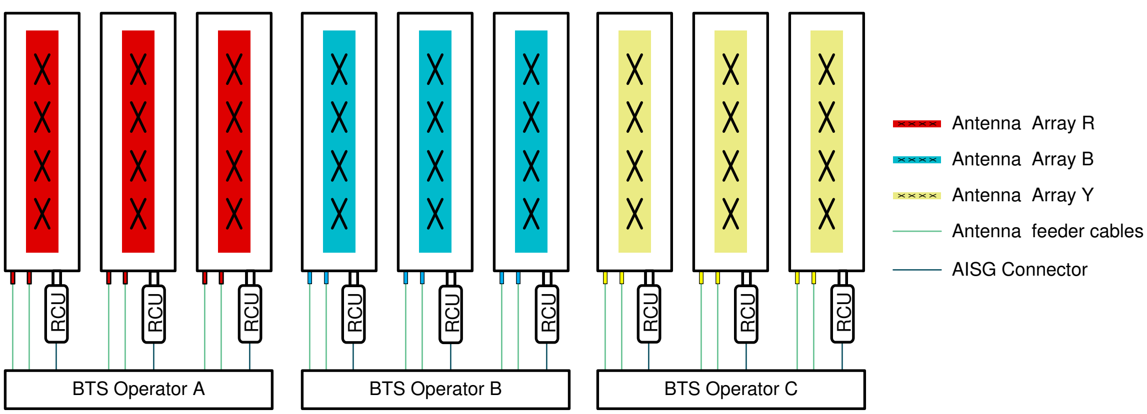

Figure 1-1. Single-band Antenna Deployment for Single Mode of Three Operators

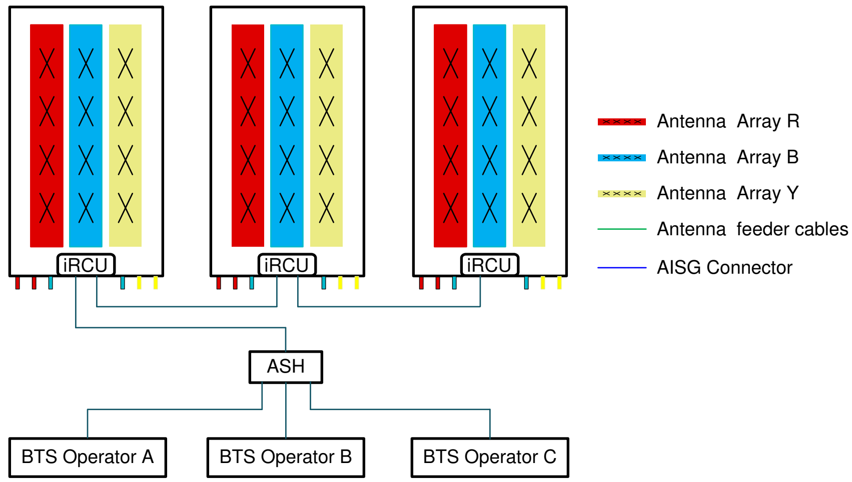

Figure 1-2. Multi-band Antenna Deployment for Single Mode of Three Operators using ASH

ASH is one type of antenna line devices (ALDs) that need to meet the requirements of AISG v2.0 or v3.0 specification. AISG connector is manufactured according to the AISG Standard with power and RS-485 interfaces. Table 1-1 shows the AISG connector pin-out according to AISG v3.0.

Table 1-1. AISG Connector Pin-Out According to AISG v3.0

Pin No.	Signal	Requirement	Description
1	Not Used		DC supply pin in earlier AISG versions
2	Not Used		DC supply pin in earlier AISG versions
3	RS-485 B	Mandatory	Line voltage Vb
4	Not Used		Optional RS-485 ground in earlier AISG versions
5	RS-485 A	Mandatory	Line voltage Va
6	10 V – 30 V DC	Mandatory	Normal 24 V DC
7	DC return	Mandatory	
8	Not Used		

1.2 AISG v3.0 Requirements for ALDs DC Power Supply

In AISG v2.0 specification, there are no specified requirements for DC power-up of ALDs. However, in AISG v3.0 specification, Some DC power-up requirements are fulfilled during start-up at any ALD voltage within the AISG specified operating voltage range (10 V – 30 V DC). There are two mandatory requirements:

Allowed initial energy consumption at power-up:

The initial consumed energy per AISG DC input port shall be less than or equal to 1 mJ during the first 0.2 milliseconds.

Allowed initial current consumption at power-up:

The peak current consumption from 0.2 milliseconds to 50 milliseconds shall be less than or equal to 2 watts divided by 30 volts. The peak current consumption from 50 milliseconds to 10 seconds shall be less than or equal to 2 watts divided by the ALD voltage.

For the first requirement, it means the average power during the first 0.2 milliseconds should be less than 5 watts (1mJ / 0.2 ms = 5 watts). The AISG DC input voltage varies from 10 V to 30 V. Taking the worst case, for example, 30 V, it means the average current should be less than 167mA (5 watts / 30 V = 167mA). For the second requirement it means the peak current from 0.2 milliseconds to 50 milliseconds should be less than 67mA (2 watts / 30 V = 67mA). And taking the worst case, for example, 30 V, from 50 milliseconds to 10 seconds, the peak current should be also less than 67mA (2 watts / 30 V = 67mA).

To meet the requirements of AISG v3.0 specification for ALDs DC power supply, Inrush current control circuitry needs to be added into the powepath of ALDs.

2 PowerPath Management Solution for ASH

Normally up to three or six independent operators can share multi-port antennas using ASH. The ASH is deployed between operators and Antennas and connects them through AISG connectors. ASH works like a router, that not only RS-485 route, but also has power route. Through the AISG interface, each operator's BTS can power iRCU. Since power supplies coming from BTSs vary from 10 V to 30 V, the powerpath of ASH needs to be correctly managed to connect all powers in parallel.

2.1 Simple ORing Diodes Solution

The simple way to connect power supplies in parallel is using ORing diodes. Figure 2-1 shows ORing diodes solution for ASH powerpath management.

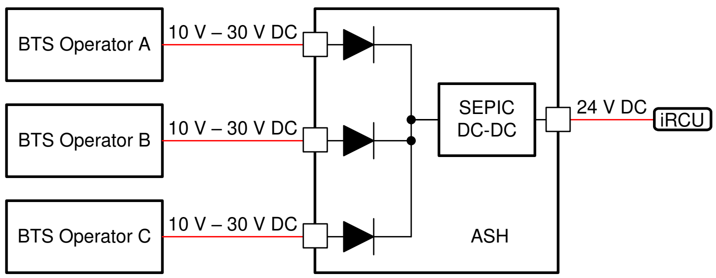

Figure 2-1. ORing Diodes Solution for ASH PowerPath Management

With ORing diodes, only the highest of the input voltages are passed to the output and others are ignored. More importantly, due to the unidirectional conductivity of diodes, there are no reverse sinking current from the highest input voltage branch to other input voltage branches.

ORing diodes solution can be realized with traditional discrete silicon or Schottky diodes. This is a simple and low cost solution. However, there still have some problems.

First, power loss across the forward voltage drop of diodes can be very high which may significantly reduce the system efficiency.

Second, power supplies coming from BTSs vary from 10-V to 30-V. Even if one power branch has only 100mV higher than other branches, then this highest one will provide all the current to the load alone and others contribute none current. Here brings other two problems. Suppose that at input ports of ASH, operator A's BTS provides 28-V DC, operator B's BTS provides 26-V DC and operator C provides 24-V DC. One problem is that operator A's BTS has to provide load current even if operator B's or C's BTS requests to control the antenna RET by iRCU. Another problem is that operator B's or C's BTS will report power fault during the period when they requests to control the antenna RET, because no current consumption coming from operator B's or C's BTS are detected during RET operation.

The second problem can easily be solved by adding dummy constant current source to deceive BTS, that are discussed in TPS2660 Application Example for ASH PowerPath Management. For the first problem, operator with the highest input voltage can take on all electricity bills although an antenna sharing scenario of multi-operator. All operators split the bill, it is still unfair because frequencies of RET control request coming from operators are different. For 2G or 4G antenna that does not adjust too much, this might not be a problem. However, 5G antenna needs to adjust frequently in real time due to massive MIMO and beamforming techniques. So, operators need to separately settle electricity bills based on their actual needs rather than simply split the bill. To solve this problem, a series switch, typically high-side MOSFET, needs to be added into each BTS's powerpath for the enable and disable purpose.

Third, ORing diodes solution cannot provide inrush current control which is mandatory in AISG v3.0.

2.2 Discrete Diodes and P-MOSFETs Solution

To have functions of powerpath enable and disable, as well as inrush current control, discrete circuitry solution is used in some ASH products. Figure 2-2 shows one discrete diodes and P-MOSFETs Solution for ASH powerpath management.

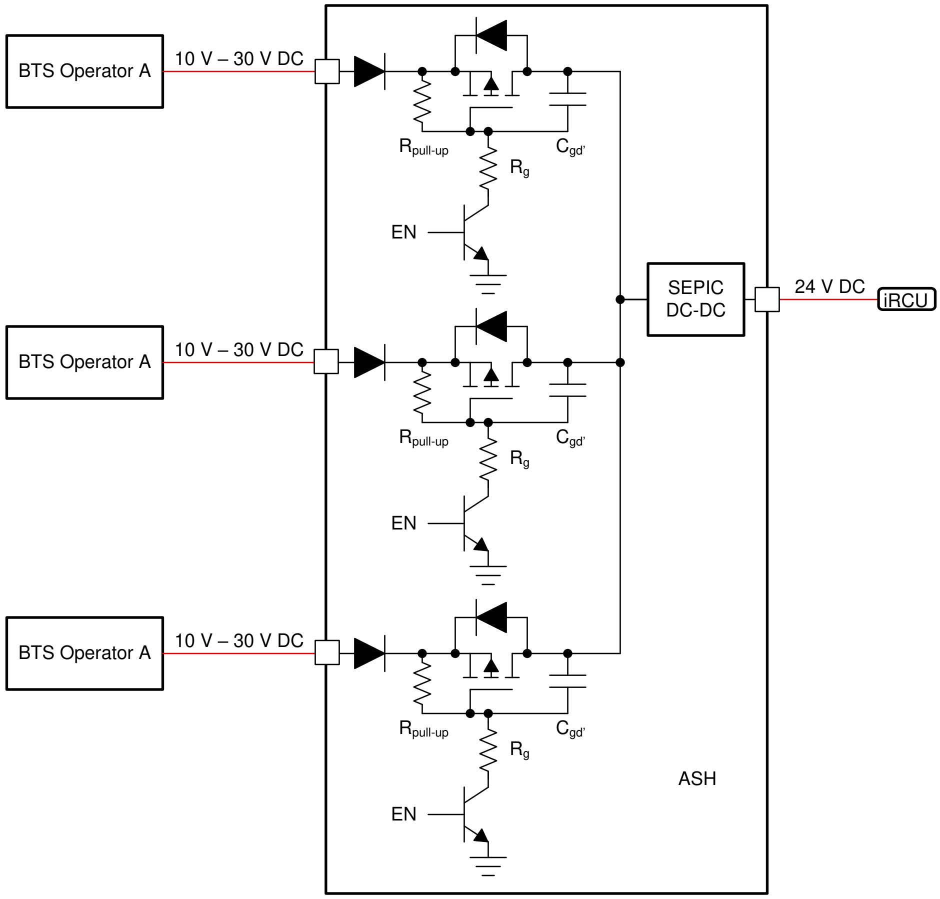

Figure 2-2. Discrete Diodes and P-MOSFETs Solution for ASH PowerPath Management

The series P-MOSFET in the powerpath works as a switch to enable or disable the corresponding BTS power supply. The inrush current, or say the P-MOSFET slew rate dV_{SD}/dt, can be controlled by the gate resistance R_g and additional large gate-drain capacitance $C_{gd'}$.

In order to have well slew rate control performance, values of pull up resistance $R_{pull-up}$, gate resistance R_g and gate-drain capacitance $C_{gd'}$ need to be well designed with gate characteristic of the P-MOSFET being considered. Inevitably, sometimes it needs to iterate the design. In addition, discrete solution needs a lot of components which occupy a lot of space. What's more, the total cost of discrete solution may be not competitive to integrated IC solution by using P-MOSFET. Since with the same $R_{DS(ON)}$, P-MOSFET is more expensive than N-MOSFET. For more information about discrete solution, refer to *Basics of eFuses Application Note*.

2.3 TI Integrated Solution Using eFuse TPS2660

The TPS2660x devices are integrated, high voltage eFuse with a full suite of powerpath protection features. It has maximum 60 V operating voltage and 2 A current. It can withstand and protect the loads from positive and negative supply voltages up to ±60 V. It also has features of adjustable current limit, inrush current control, overload and short circuit protections etc. These features make it suitable for ASH products which are mounted in the antenna tower and need to have well performance of lightning resistance, powerpath management and load protection etc.

As shown in Figure 2-3, TPS2660x has integrated back to back FETs that can provide reverse current blocking feature. When the OUTPUT voltage is higher than the INPUT voltage, the body diode of N1 can block the reverse current flowing from OUPUT to INPUT. The total $R_{DS(ON)}$ of MOSFETs N1 and N2 is 150 mΩ. A fast hysteresis comparator controls conduction and blocking of the internal FETs. The internal FETs are turned off within 1.5 µs (typical) as soon as the differential forward voltage $V_{(IN)} – V_{(OUT)}$ falls below –110 mV and turned on within 40 µs (typical) once $V_{(IN)}– V_{(OUT)}$ exceeds 100 mV. For the application of redundant power supply, TPS2660x acts as an active ORing with advantages of much lower voltage drop and associated power loss than traditional discrete silicon or schottky ORing diodes. For more application details, refer to the *TPS2660x 60-V, 2-A Industrial eFuse With Integrated Reverse Input Polarity Protection* data sheet.

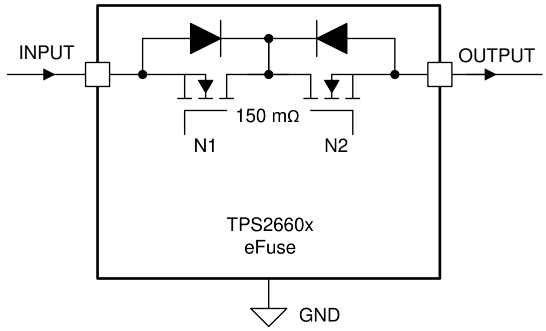

Figure 2-3. TPS2660x - Back to Back FETs for Reverse Current Protection

As shown in Figure 2-4, with only an external capacitor C_{dVdT} being connected from the dVdT pin to RTN pin, the slew rate of the output voltage at power-on can be controlled linearly. Hence, the inrush current can be controlled, correspondingly.

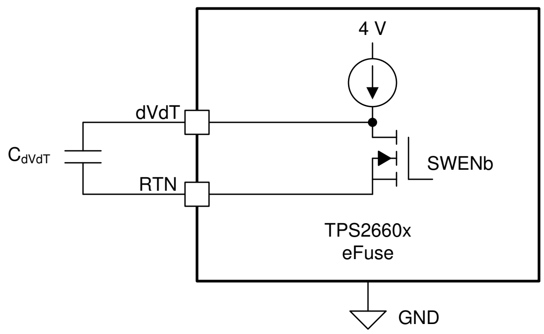

Figure 2-4. Output Slew Rate Control Set by CdVdT

As shown in Figure 2-5, TPS2660x also has a shutdown pin which provides external control for enabling and disabling the internal FETs as well as placing the device in a low current shutdown mode. The low current shutdown control makes TPS2660x have the ability of powerpath enable and disable, and extra low quiescent current (typical 20 µA) in shutdown state. The internal FETs and hence the load current can be switched off by pulling the SHDN pin below 0.76 V threshold with a micro-controller GPIO or a pull-down resistor. To enable the device, SHDN must be pulled up to at least 1 V. After enabling the device, the internal FETs turn on with dVdT mode.

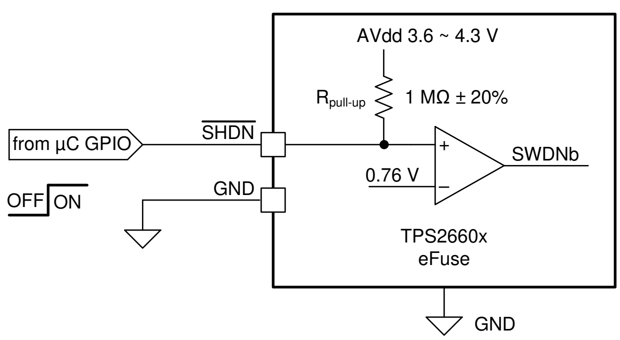

Figure 2-5. Enable and Disable Control

Apart from above mentioned features, TPS2660xx also provides other features including overcurrent, overvoltage, undervoltage, short circuit and reverse polarity protections and so on. With only a few external components (a resistor R_{ILIM} for current limit setting and a capacitor C_{dVdT} for output voltage ramp rate setting), eFuse TPS2660xx helps to simplify the system design, reduce board size, and enhance robustness, compared to traditional discrete diodes and P-MOSFET solutions.

The next section introduces an application example for powerpath management of the antenna sharing hub using the TI device TPS2660x eFuse to solve above issues and meet the requirements of AISG v3.0 specification.

3 TPS2660 Application Example for ASH PowerPath Management

Figure 3-1 shows the typical ASH system block diagram using TPS26600. Up to three or six independent operators share iRCU control by the ASH. Power coming from each operator first passes the lightning and surge protection circuit, and then goes into eFuse TPS26600. All outputs of TPS26600 are connected together as a whole parallel power supply and then regulated to 24-V DC through the SEPIC converter. TPS26600 can be enabled or disabled by the microcontroller's GPIO. The microcontroller can also transmit and process bi-directional commands and data from operators and iRCU through RS-485 transceiver.

The microcontroller is powered by the Buck converter with whose input being directly connected to all powerpaths through simple ORing diodes. The reasons why using ORing diodes here are because micro controller needs to be always powered in working or standby modes; and its power consumption is negligible compared to stepper motor running iRCU, so, ORing diodes solution is the most cost-effective way. Note that each powerpath also has a dummy constant current source, that is used to bypass operator's load detection.

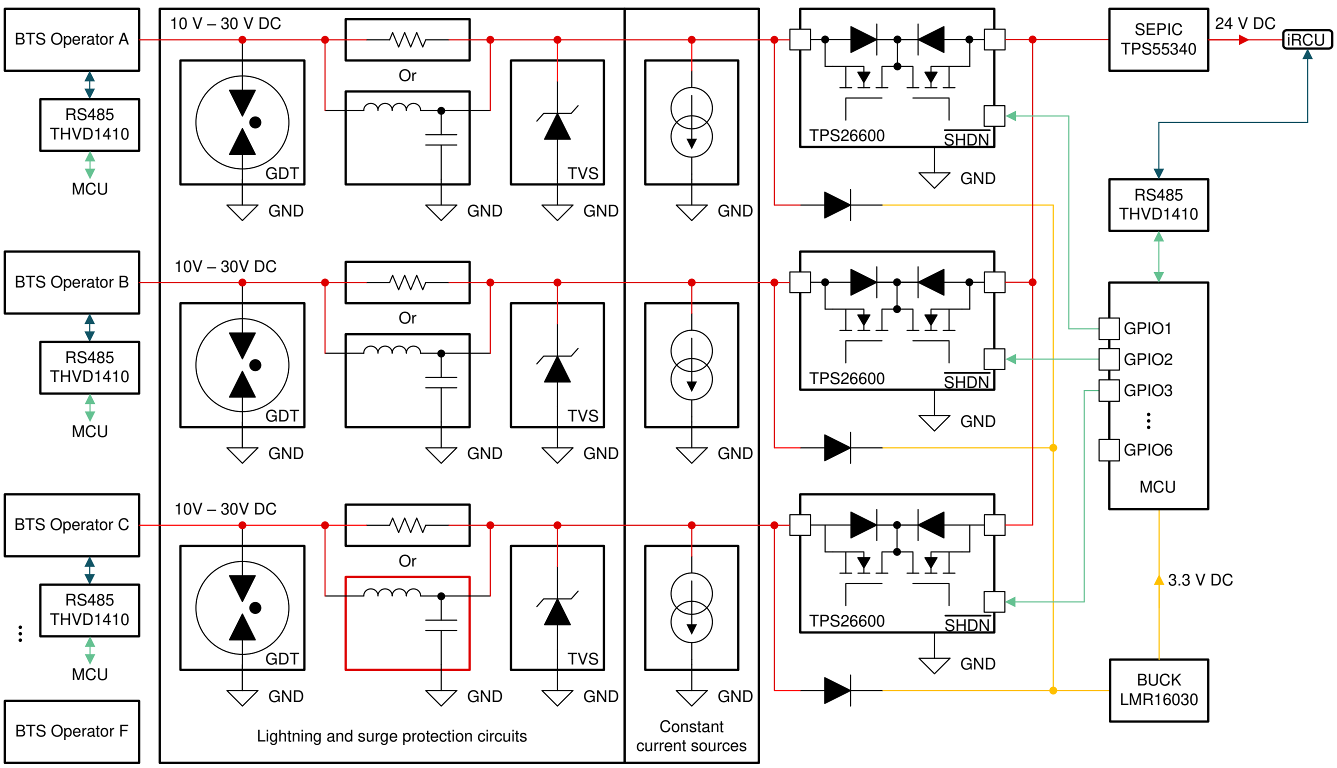

Figure 3-1. Typical ASH System Block Diagram Using TPS26600

3.1 How Does ASH Work

The ASH is deployed between operators and antennas (iRCU). Before the ASH starting up, all TPS26600 are disabled by external pull-down resistors. The microcontroller is always powered either in standby or working mode to maintain communications with BTS operators.

When the ASH starts up, all TPS26600 will be enabled through microcontroller's GPIO control (now in standby mode) and their inrush current control works to limit the output slew rate to conform AISG v3.0's requirements. In standby mode at when no operator requests to adjust the antenna, the microcontroller in iRCU still needs to maintain communications with BTS operators, so that iRCU must be powered with 24V DC either in standby or working mode. In this situation, only the operator with the highest input voltage powers the microcontroller in iRCU while other operators don't provide power (Microcontroller's power consumption is negligible compared to that of stepper motor running).

Here it brings a problem that all operators have communications with the iRCU, while only the operator with the highest input voltage powers the microcontroller. Based on BTS protocol requirements, the BTS needs to detect load power consumption through current sensing in real time. For the situation that there has communication between BTS and iRCU but no power output from the BTS itself, the BTS will mistakenly believe that there has powerpath fault between BTS and iRCU. So, usually a dummy constant current source is added into the powerpath to bypass the protocol limitation of operator BTS's load detection.

After the ASH finishing start-up, if one operator, operator A for instance, requests to adjust the antenna (now in working mode), all others TPS26600 will be disabled. So, only operator A will power the iRCU to make the stepper motor run. When no operator requests to adjust the antenna, all TPS26600 are enabled again and both ASH and iRCU enters standby mode again.

Here you might question why ASH enables one TPS26600 at a time? The reason is that when you disable one TPS26600 and enable another TPS26600, there is blank time with the risk that no one can power the microcontroller in iRCU. This is why all TPS266600 needs to be enabled in standby mode; one TPS26600 is enabled and others are disabled in working mode.

3.2 TPS26600 Application Circuit

Figure 3-2 shows one practical TPS26600 circuit which satisfies the inrush current control requirements described in AISG v3.0 Requirements for ALDs DC Power Supply .

In this simulation design case, the DC input voltage can vary from 10 V to 30 V; the over load current limit is set at 1.2 A with R_{ILIM} = 10 Kohm and the corresponding current monitoring resistor R_{IMON} is set at 27.4 Kohm; the undervoltage lockout (UVLO) and overvoltage protection (OVP) are correspondingly set at 8V and 60V, with R_1 = 1.3 Mohm, R_2 = 196 Kohm and R_3 = 30.1 Kohm; the 10 Kohm pull down resistor R_{SHDN} at the SHDNb pin sets TPS26600 be disabled in the initial state and the PWL source VPWL acts as microcontroller's GPIO control signal which can enable or disable TPS26600; the load is set at constant 0.1 Watts to simulate the standby power of the latter SEPIC circuit and iRCU; the output capacitor (including the input capacitor of the latter SEPIC circuit) is assumed to 220uF.

Using equations $t_{dVdT} = C_{out} \times (V_{IN} / I_{INRUSH})$ and $C_{dVdT} = t_{dVdT} / (8 \times 10_3 \times V_{IN})$, C_{dVdT} is selected to 680 nF to set the inrush current around 40mA. Note that for different output capacitor, the inrush current varies. Hence, the value of C_{dVdT} needs to be adjusted to satisfy the inrush current requirements. For more calculation details, refer to the *TPS2660x 60-V, 2-A Industrial eFuse With Integrated Reverse Input Polarity Protection* data sheet.

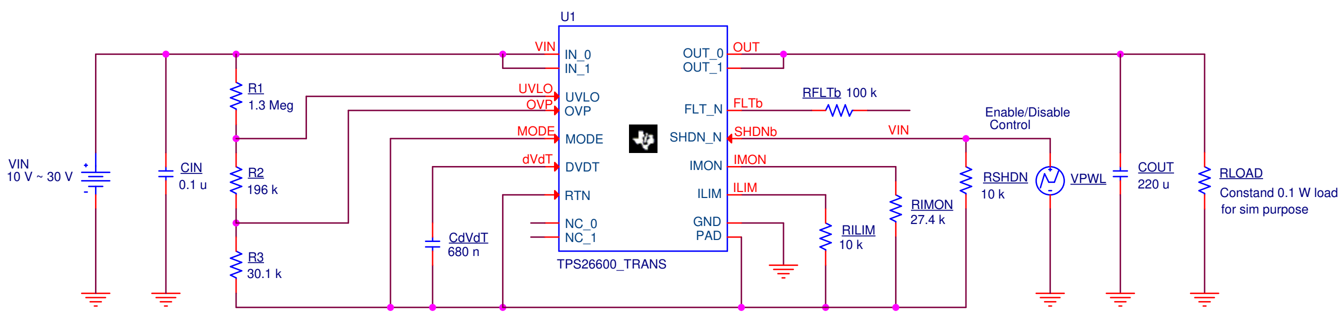

Figure 3-2. One Practical TPS26600 Circuit for ASH PowerPath Management

3.3 Lightning and Surge Protection Circuit

The lightning and surge protection circuit usually consists of a gas discharge tube (GDT), a current limiting resistor, and a TVS diode to have fast response to transient over-voltage events and the ability to dissipate large amounts of energy, which provides the ASH with lightning surge protection.

In some cases, the current limiting resistor might not be very fast to respond, a proper LC filter could have better performance to reduce the steep voltage and current rise rate of lightning waves.

3.4 Dummy Constant Current Source Circuit

As previously described, a dummy constant current source is usually added into the powerpath to bypass the protocol limitation of operator BTS's load detection. There are many ways to construct constant current source, such as Zener diode current source, op-amp current source and BJT current source etc. The load detection threshold of BTS is 20mA. So, BJT current source solution with 2 NPN or PNP transistors, which is low cost and has thermal compensation, is widely used in ASH application. Figure 3-3 shows a simple 27mA BJT constant current source that satisfies the load detection threshold requirement.

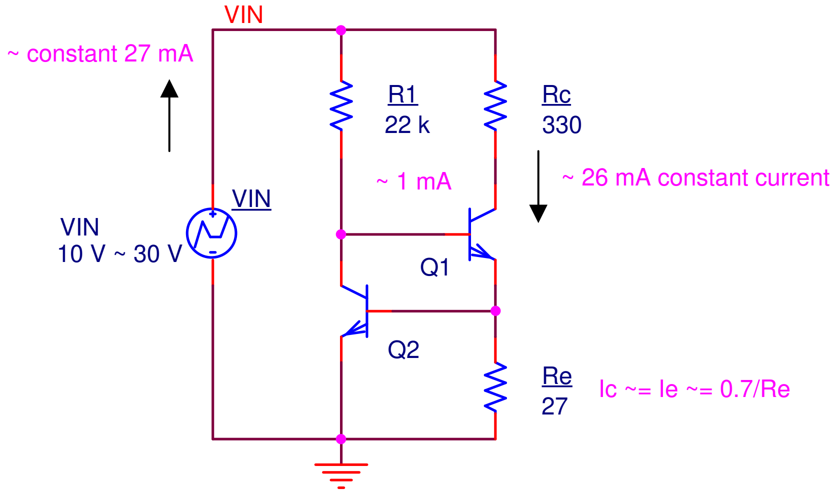

Figure 3-3. A Simple 27mA BJT Constant Current Source

4 Optimizing the Solution Using TPS26400 eFuse

The recently released eFuse *TPS26400* is a low voltage version of TPS2660 eFuse and provides same suit of protection features as TPS2660 device. TPS26400 has 42 V as operating voltage and supports load currents up-to 2 A. As the antenna sharing hub uses 30 V as maximum operating voltage, TPS26400 provides a cost-effective optimum solution to select the source of choice and reliable protection in each of the power path.

5 Bench Test and Result Reference

5.1 Bench Test Setup

Figure 5-1 shows the bench test configuration of TPS26600 ASH powerpath management application circuit shown in Figure 3-2 by modifying *TPS26600-02EVM Evaluation Module for TPS2600x*.

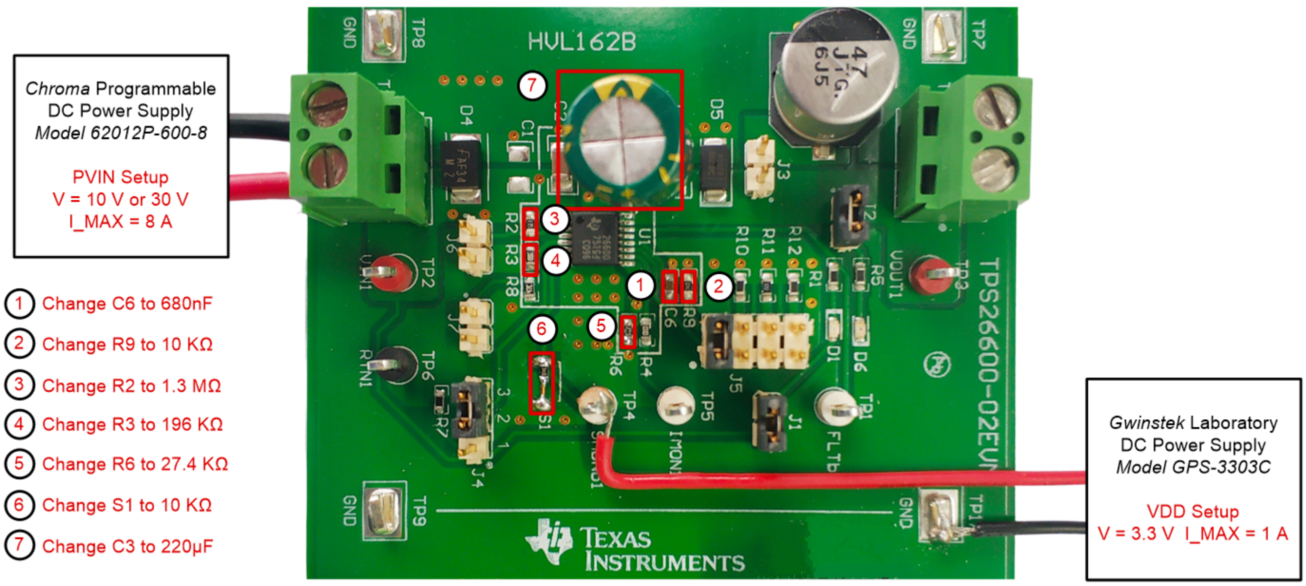

Figure 5-1. Bench Test Configuration of TPS26600 ASH PowerPath Management Application

5.2 Bench Test Waveforms

Figure 5-2 and Figure 5-3 correspondingly show inrush current control waveforms at 10V input and 30V input, without load. Figure 5-4 and Figure 5-5 correspondingly show inrush current control simulation waveforms at 10-V input and 30-V input, with 0.1 watts load. It can be seen from these waveforms that the inrush current satisfies requirements described in AISG v3.0 Requirements for ALDs DC Power Supply .

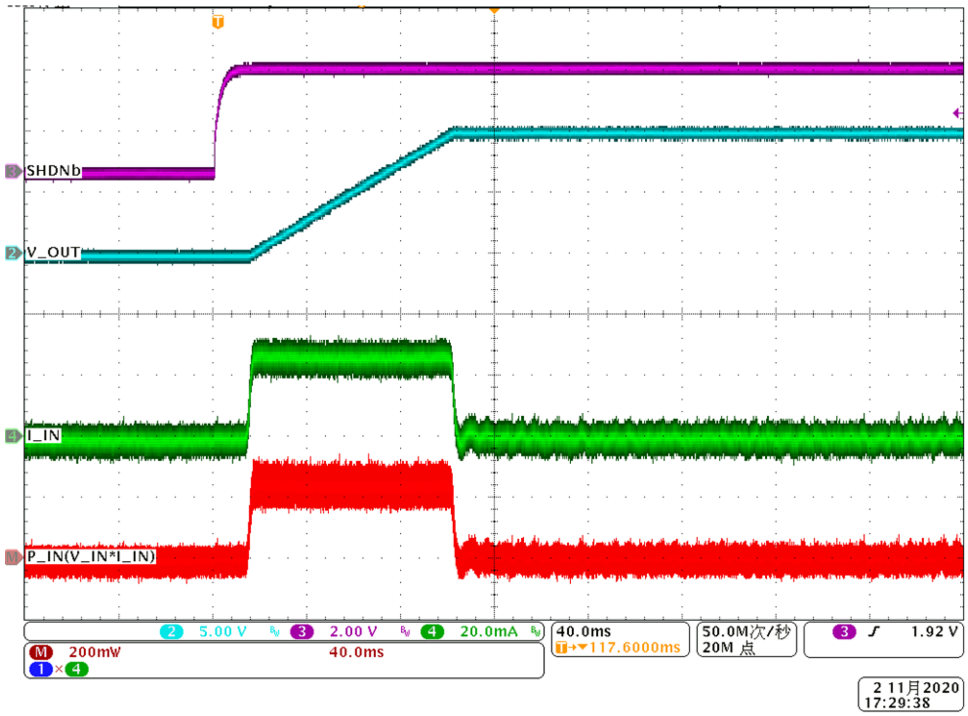

Figure 5-2. Start-up Inrush Current Control Waveforms at 10 V Input, without Load

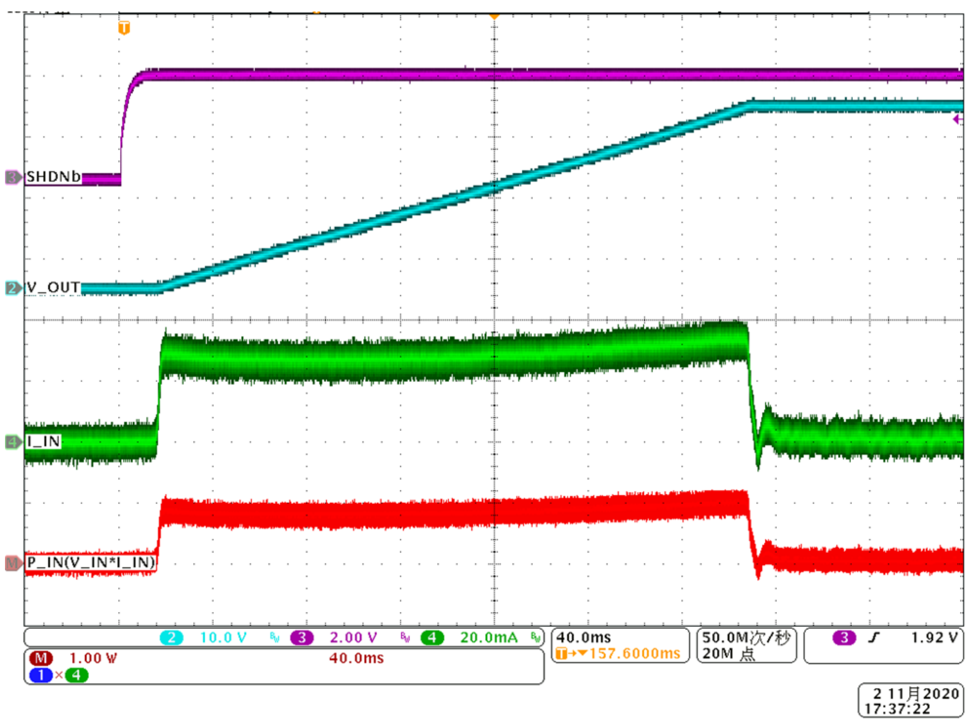

Figure 5-3. Start-up Inrush Current Control Waveforms at 30 V Input, without Load

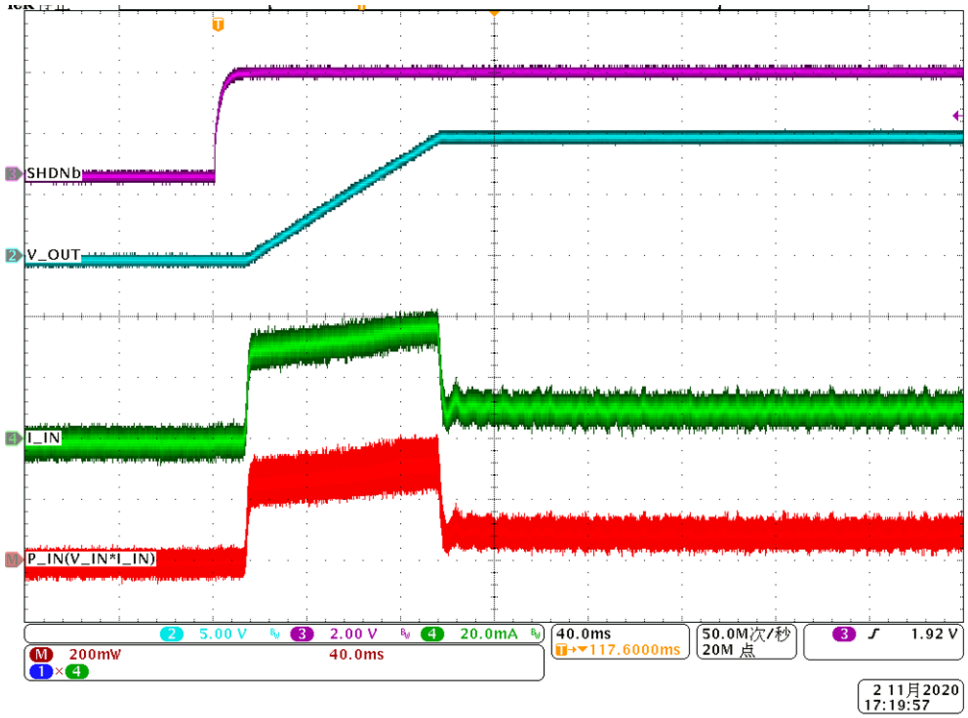

Figure 5-4. Start-up Inrush Current Control Waveforms at 10 V Input, 1Kohm Load

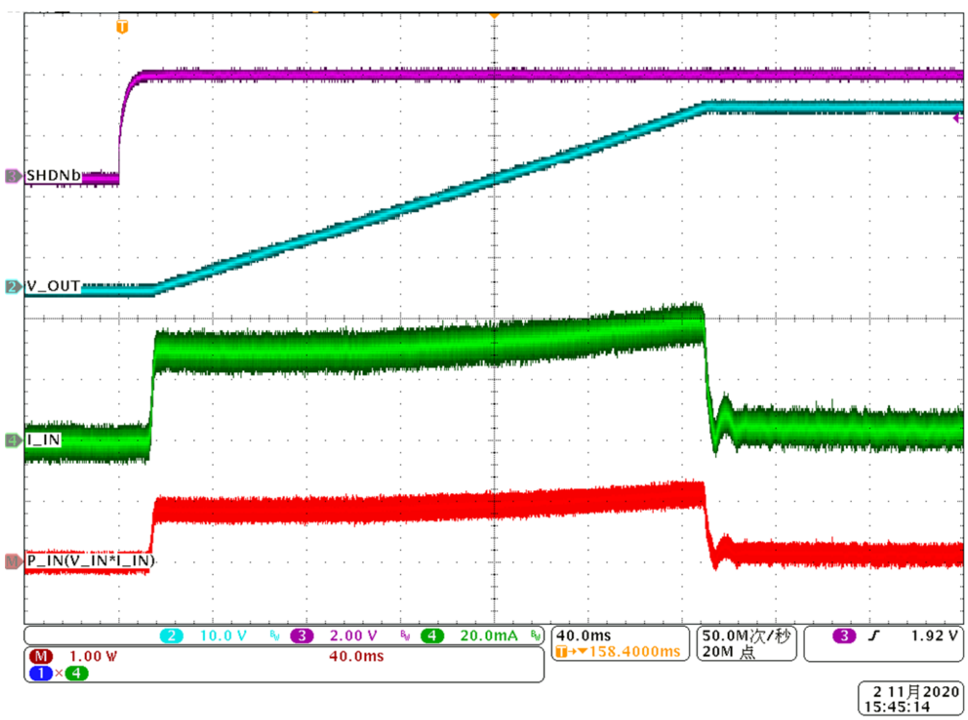

Figure 5-5. Start-up Inrush Current Control Waveforms at 30 V Input, 9Kohm Load

6 Conclusion

This application note provides an integrated powerpath management solution for antenna sharing hub using the TI device TPS2660x to meet the inrush current requirements of AISG v3.0 specification and have enable and disable features. The traditional and new sharing antenna deployments, and AISG v3.0, are first introduced to bring in the reason of powerpath management of ASH.

Then, traditional ORing diode and discrete P-MOSFETs Solutions are analyzed with their advantages and advantages. Next, the application example for ASH PowerPath Management with TPS2660x eFuse is discussed in detail. Finally, bench test verifies the practicability of this TPS2660x eFuse solution.

7 References

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