Mini-Circuits®

# ISC-2425-25+ Safe Operating Area Apps Note

AN-50-003

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# 1. Introduction

The “Safe Operating Area” **(SOA)** concept tries to define operating conditions for the RF generator which assure the reliability, longevity and safe operation of the device. This also means that operating the generator “outside” of the SOA could potentially damage the unit or at least reduceits expected lifetime.

The SOA considers a number of parameters:

- Temperature of the amplifier at critical components
- The amount of reflected RF power (that needs to be dissipated inside the amplifier) or the sum of the forward and reflected RF power (to limit the total stress on transmission lines inside the amplifier that are exposed to forward and reflected power components)
- The total dissipated power, which is the sum of DC power into the amplifier plus the reflected RF power minus the forward RF power. Hence, this parameter also takes into account the effi-ciency of the device.
- Furthermore, watchdog timeouts can be enabled that can also be used for communication and interaction between an ISC controller and a host, and the ISC controller and the amplifier unit connected to it.

The user should take good care when using or modifying the protection commands described in this application note, as a wrong configuration may disable or hamper protective functions and the unit might be damaged during operation in adverse conditions.

# 2. Recommended default settings

As a rule of thumb, the default SOA settings for generator chains should be:

- Temperature of the amplifier at critical components:
  55˚C for water cooled systems75˚C
  for air-cooled systems

- The amount of reflected RF power:
  25% of the nominal power rating of the PA (in mode 0) 125% of
  the nominal power rating of the PA (in mode 1)**Note:** See
  section 3.3 for more details.

- The total dissipated power:
  High limit: Nominal PA output power * 2 Shutdown
  limit: Nominal PA output power * 2.2

# 3. Detailed command explanation

## 3.1 $SOA – SET SOA CONFIGURATION

This command configures the enable state of the SOA's protection systems.SOA has the following protection systems in place:

- Protection against high temperatures.
- Protection against software timeouts / freezes.
- Protection against excessive reflections
- Auto-disable RF Power if the board status is not polled frequently enough.
- Protection against excessive total dissipation inside the amplifier

**Remark:** This command does not adhere to established syntax. Its output is unique.

### SYNTAX:

| | |
|---|---|
| **Input:** | $SOA, [channel] , [temperature enable] , [watchdog enable] , [reflection enable] ,[external watchdog enable] , [dissipation enable] |
| **Output:** | $SOA Tmp: [0/1] S11: [0/1] eWD: [0/1] Diss: [0/1] |

- **[channel]** – Channel identification number.
- **[temperature enable]** – Enable state of the temperature protection system.0 – OFF
  1 – ON
- **[watchdog enable]** – Enable state of the software timeout/freeze protection system.
  This parameter is ignored. Software watchdog is always enabled.
- **[reflection enable]** – Enable state of the RF power reflection protection system.0 – OFF
  1 – ON
- **[external watchdog enable]** – Enable state of the board status polling protection system.0 – OFF
  1 – ON
- **[dissipation enable]** – Enables the dissipation protection, i.e. a maximum amount of dissipatedpower inside the amplifier can be set. The dissipated power is the sum of the reflected RF power and the dissipation due to the RF generation process.

**In the return line:**

- **Tmp = [temperature enable]**
- **S11 = [reflection enable]**
- **eWD = [external watchdog enable]**
- **Diss = [dissipation protection enable]**

**Example:**

| | |
|---|---|
| **Input:** | $SOA, 1, 0, 0, 0, 1, 0 |
| **Output:** | $SOA Tmp: 0 S11: 0 eWD: 1 Diss: 0 |

This enables the external watchdog, but disables the other protection systems, except the software watchdog which is permanently enabled.

## 3.2 $SOG – GET SOA CONFIGURATION

This command returns the enable state of the SOA's protection systems.

### SYNTAX:

| | |
|---|---|
| **Input:** | $SOG, [channel] |
| **Output:** | $SOA Tmp: [0/1] S11: [0/1] eWD: [0/1] Diss: [0,1] |

- **[channel]** – Channel identification number.

**In the return line:**

- **Tmp = [temperature enable]** – Enable state of the temperature protection system.
- **S11 = [reflection enable]** – Enable state of the reflection protection system.
- **eWD = [external watchdog enable]** – Enable state of the board status polling protectionsystem.

**Example:**

| | |
|---|---|
| **Input:** | $SOG, 1 |
| **Output:** | $SOA Tmp: 0 S11: 0 eWD: 1 Diss: 0 |

This indicates the external watchdog protection system is enabled, but the other protections systems are disabled, except for the software watchdog, which is permanently enabled.

## 3.3 $SPS – SET REFLECTED POWER SOA CONFIGURATION

This command configures the reflected power values at which SOA takes action.

One of the features of the SOA is protection against excessive reflected power.
Excessive reflection occurs when there is a bad match at the output and RF returns to thegenerator.

The SOA has two reactions to excessive dissipation, depending on the severity:

- If the reflection is **high**, but still tolerable:
- Raise a 'High Reflection' error.
- If the reflection is dangerously high:
- Raise a **'Shutdown Reflection'** error and shutdown RF power.

### SYNTAX

| | |
|---|---|
| **Input:** | $SPS, [channel] , [high reflection] , [shutdown reflection] , [reflection limit mode] |
| **Output:** | $SPS, [channel], OK |

- **[channel]** – Channel identification number.
- **[high reflection]** – The reflection value in dBm at which the 'High Reflection' situation is signaledby the SOA. It will be reported upon an $ST command.
- **[shutdown reflection]** – The reflection value in dBm at which the 'Shutdown Reflection' reactionis performed by the SOA: RF will be switched off and the corresponding error bit will be set.
- **[reflection limit mode]**:
  0: default "reflection" SOA mode; the algorithm reacts only to the amount of reflected power.1: the algorithm sums both the forward *and* the reflected power to determine whether any limit has been reached.

**Note:** which mode to use depends on the internal layout of the amplifier. In fact, the limit shouldbe set based on the "weakest" spot/trace in the amplifier. Generally speaking, mode 1 is preferred.

A conservative setting would be the nominal value of the PA's output power + 33%. This mode also allows high reflected powers at low forward powers, which may readily exist in multi-channelsystems.

**Example**

| | |
|---|---|
| **Input:** | $SPS, 1, 53, 54, 0 |
| **Output:** | $SPS, [channel], OK |

This sets the 'High Reflection' and 'Shutdown Reflection' protection values to 53 dBm (200W)and 54 dBm (250W) respectively.

If the limit of 53 dBm reflection is exceeded, the corresponding bit is set in the status word.If the limit of 54 dBm reflection is exceeded, the RF is shut down by SOA.

## 3.4 $SPG – GET REFLECTED POWER SOA CONFIGURATION

This command returns the reflection values at which SOA takes action.

### SYNTAX:

| | |
|---|---|
| **Input:** | $SPG, [channel] |
| **Output:** | $SPG, [channel] , [high reflection] , [shutdown reflection] |

- **[channel]** – Channel identification number.
- **[high reflection]** – The reflection value in dBm at which the 'High Reflection'reaction is performed by the SOA.
- **[shutdown reflection]** – The reflection value in dBm at which the 'ShutdownReflection' reaction is performed by the SOA.

**Example:**

| | |
|---|---|
| **Input:** | $SPG, 1 |
| **Output:** | $SPG, 1,53.000000, 54.000000 |

This indicates the 'High Reflection' and 'Shutdown Reflection' protection values areconfigured to 53 dBm (200W) and 54 dBm (250W) respectively.

## 3.5 $STS – SET TEMPERATURE SOA CONFIGURATION

This command configures the temperature values at which SOA takes action.One of the features of the SOA is protection against excessive temperatures.
Excessive temperatures can occur for any number of reasons: side effects of high RF powerreflection, faulty cooling, excessive use, etc.

The SOA has two reactions to excessive temperatures, depending on the severity:

- If the temperature is high, but still tolerable:
- Raise a 'High Temperature' error.
- If the temperature is dangerously high:
- Raise a 'Shutdown Temperature' error and shutdown RF power.

### SYNTAX:

| | |
|---|---|
| **Input:** | $STS, [channel] , [high temperature] , [shutdown temperature] |
| **Output:** | $SDS, [channel], OK |

- **[channel]** – Channel identification number.
- **[high temperature]** – The temperature value in °C at which the 'High Temperature' situation issignaled by the SOA. The corresponding bit in the status word is set and can be read with an $ST command.
- **[shutdown temperature]** – The temperature value in °C at which the 'Shutdown Temperature'reaction is performed by the SOA. The generator will be switched off and the corresponding error bit will be set in the status word.

**Example:**

| | |
|---|---|
| **Input:** | $STS, 1, 80, 90 |
| **Output:** | $STS, 1, OK |

This sets the 'High Temperature' and 'Shutdown Temperature' protection values to 80°C and 90°Crespectively.

If the limit of 80°C temperature is exceeded, the status bit is set.
If the limit of 90°C temperature is exceeded, the RF is shut down by SOA and the error bit is set.

## 3.6 $STG – GET TEMPERATURE SOA CONFIGURATION

This command returns the temperature values at which SOA takes action.

### SYNTAX:

| | |
|---|---|
| **Input:** | $STG, [channel] |
| **Output:** | $STG, [channel] , [high temperature] , [shutdown temperature] |

- **[channel]** – Channel identification number.
- **[high temperature]** – The temperature value in °C at which the 'High Temperature' situation issignaled by the SOA.
- **[shutdown temperature]** – The temperature value in °C at which the 'Shutdown Temperature'reaction is performed by the SOA.

| | |
|---|---|
| **Input:** | $STG, 1 |
| **Output:** | $STG, 1, 80.0, 90.0 |

This indicates the 'High Temperature' and 'Shutdown Temperature' protection values areconfigured to 80°C and 90°C respectively.

## 3.7 $SDS – SET DISSIPATION SOA CONFIGURATION

This command configures the dissipation value at which SOA takes action, as well as the grace period allotted before SOA shuts down RF in case of communication failure with power supplies.

One of the features of the SOA is protection against excessive power dissipation inside a generator. Excessive power dissipation occurs when an RF system draws a disproportionate amount of current from its power supply (PSU) relative to the amount RF energy that is transmitted into a load. The problem can be further aggravated by reflected RF power as well.

Dissipation is measured in watt. The formula used to calculate it is the following:

*Dissipation(W) = PSU Power(W) - FWD Power(W) + RFL Power(W)*

The SOA has two reactions to excessive dissipation, depending on the amount:

- **If the dissipation is high, but still tolerable:**
  Raise a 'High Dissipation' warning. The respective bit is set in the status word and can be readvia a $ST command.
- **If the dissipation is dangerously high:**
  Raise a 'Shutdown Dissipation' error and shutdown RF power. The respective bit is set in thestatus word.

Calculating the dissipation value necessitates communication with a power supply to ascertain the amount of power being drawn. This presents an opportunity for communication failure. Failure to acquire the PSU power means the dissipation cannot be calculated. Normally this would result in an immediate halt of RF power by the SOA, however this may not always be the desired behavior.

To counteract the occasional communication hiccup a grace timeout period can be allotted to the dissipation SOA, providing an opportunity to recover from the communication fault.

### SYNTAX:

| | |
|---|---|
| **Input:** | $SDS, [channel] , [high dissipation] , [shutdown dissipation] , [grace period] |
| **Output:** | $SDS, [channel], OK |

- **[channel]** – Channel identifier number.
- **[high dissipation]** – The dissipation value in watt at which the 'High Dissipation' reaction is per-formed by the SOA. The corresponding bit is set in the status word.
- **[shutdown dissipation]** – The dissipation value in watt at which the 'Shutdown Dissipation' reaction is performed by the SOA. The corresponding bit is set in the status word and the RFoutput is switched off.
- **[grace period]** – (Optional) The grace timeout period in milliseconds during which communica-tion with the power supply may be reestablished.

**Example:**

| | |
|---|---|
| **Input:** | $SDS, 1, 1000, 2000, 10 |
| **Output:** | $SDS, 1, OK |

This sets the 'High Dissipation' and 'Shutdown Dissipation' protection values to 1 kW and 2 kWrespectively, while the 'Grace Period' is set to 5 seconds.
If the limit of 1 kW dissipation is exceeded, the respective status bit is set.
If the limit of 2 kW dissipation is exceeded, the respective status bit is set and the RF is shut downby SOA.

If a communication fault occurs with the power supply, RF shutdown is delayed by 10 milliseconds,during which the dissipation SOA attempts to re-establish communication.