Automotive Product Group
Automotive Infotainment Division

Navigation & Multimedia System & Architecture
STA8090 Antenna Detection Application Note

1 Introduction

The purpose of this document is to provide an overview on how to implement the Antenna Detection feature in terms of HW schematics and the description of the FW running in the Teseo3 chipset to drive the Antenna Detection sequence. Main objective of this Application Note is to provide guidelines that the customer can use as reference for the Antenna Detection implementation.

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None

3 Document Management

3.1 Revision History

Rev	Date	Author	Notes
1.0	2014-06-03	M. Frazzetto G. Peveraro	First Version
1.1	2015-07-21	M. Frazzetto	Fixed GPIO value for the Antenna Enable
1.2	2016-04-11	M. Frazzetto	Added Antenna Sensing description for ADC and GPIO mode

Table 1: Revision history

3.2 Acronyms

Keyword	Definition

Table 2. Acronyms

3.3 Reference Documents

[1] GNSS NMEA Interface

[2] STA8090 Firmware Configuration

3.4 Contact info

Keyword	Definition
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4 The Antenna Detection Feature

The Antenna Detection feature allows recognizing the presence of the current pumped by an active antenna plugged into the connector of the board hosting the STA8090 chipset. This can be achieved thanks to a custom design of the board and thanks to a dedicated FW implementation that make the Teseo3 chipset aware or not of the presence of the antenna.

5 Antenna Sensing Implementation

Our Antenna Detection solution provides the customer three possibilities. At configuration time the customer can choose which of the three, RF, ADC or GPIO-only implementation:

a) *RF and GPIO implementation*
Two signals, SENSE1_3V3 and SENSE2 are used to detect if the external antenna is working normally or if it is not connected or if there is a short. If the Antenna is properly working or it is open, then the SW continues to check the signals value; otherwise, if the Antenna is shorted, it allows handling a GPIO signal to switch off the Antenna and stops to check. This solution has been implemented only for STA8090 packages. The GPIO used to enable and to switch off the Antenna is the **GPIO18** for all STA8090 packages.

b) *ADC implementation*
For this implementation a reading of two ADC analog inputs, ADC1 and ADC2 channels, is used to perform a differential measurement and to compare it with a minimum and a maximum threshold.

c) *GPIO-only implementation*
Four GPIOs signals are used to detect if the external antenna is working correctly, if it is open or if there is a short. This software implementation allows handling GPIOs signals to switch off the external antenna if it is not properly working.

In addition the user can choose another way to get antenna diagnostic information: enabling the *ADC channel reading*. This possibility provides a periodic NMEA message giving information about the read values of the required ADC input channels. The user may choose the channels to read as well as the ADC sampling rate.

The Antenna Detection algorithm is a configurable SW allowing the customer to check the external antenna status. This feature is not enabled by default but it has to be switched ON configuring the application to run as RF mode or ADC mode or GPIO mode. Once enabled, the Antenna Sensing software continuously checks and updates the antenna status. The SW allows the user to have a periodic NMEA message reporting the external antenna status or to have a NMEA message that reports the antenna status only when a change occurs (The user can configure a parameter to choose one or the other option).

Another configurable parameter allows the user to enable or not the switch OFF of the external antenna in case a short is detected. This configurability is strongly recommended when Antenna Diagnostic runs as RF or GPIO mode otherwise no switch off feature is provided (for ADC mode no switch off feature is supported). When the Antenna Switch Off feature is enabled, the reading of the signals (SENSE1 and SENSE0 bits, for RF mode, GPIOs signals, for GPIO mode) to detect and update the external antenna status is performed if the antenna works as expected or if it is open, otherwise no operation is executed by the algorithm.

All the solution produce as result a NMEA out message reporting if the antenna is working properly or, otherwise, if it is open or it is shorted.

5.1 RF Antenna Sensing mode

5.1.1 Hardware Overview

The figure 1 shows a block schema for the antenna sensing circuit embedded in G4RFIP.

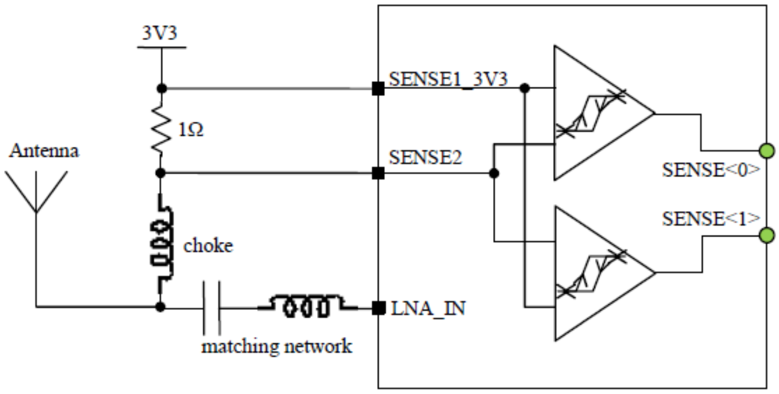


Figure 1: Antenna Sensing schematic block

It uses two comparators with a little hysteresis. It needs to be supplied by 3.3V and needs a 1Ω series resistor to convert current sunk from antenna in voltage. In the output two bits in 1.2V domain are delivered to BB.

The FW reads two bits (SENSE1 and SENSE0) and according to their values it is able to detect if the antenna is connected and properly working or if the antenna is connected but it doesn't working (antenna shorted) or if no antenna is connected (antenna open). The following tables show the relative logic:

Current sunk from antenna (when current is risig)	SENSE1	SENSE0
I < Threshold_rising_min	0	0
Threshold_rising_min <= I <= Threshold_rising_max	0	1
I > Threshold_rising_max	1	1

Table 3: Antenna Sensing relative logic when current is rising

Current sunk from antenna (when current is falling)	SENSE1	SENSE0

I >Threshold_falling_max	1	1
Threshold_falling_min <= I <= Threshold_falling_max	0	1
I < Threshold_falling_min	0	0

Table 4: Antenna Sensing relative logic when current is falling

The thresholds used by two comparators embedded in the antenna circuit are defined at silicon level and cannot be configured. They take into account a typical Active Antenna supplied by 3V3, with current consumption of ~30mA and voltage drop of 30mV. Changing the Antenna consumption (<30mA for example) the Sense series Resistor have to be changed accordingly. If Active Antenna consumption is 10mA the Sense Resistor should be 30mV/10mA = 3 Ohm.

The HW implementation is reported below in the figure 2:

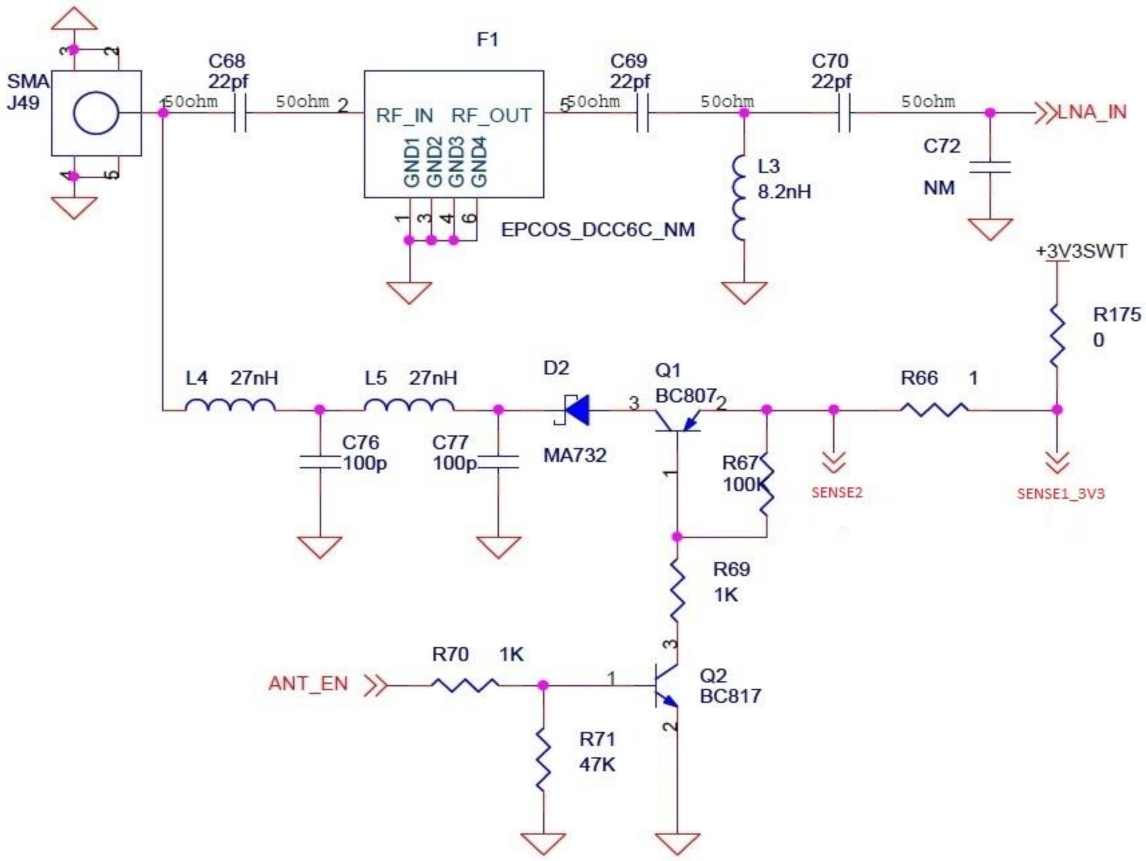


Figure 2: Antenna Sensing HW implementation

NOTE: In the SDB SENSE1_3V3 has to be connected to M13 ball and SENSE2 to L12.

5.1.2 Software Implementation

When Teseo3 is powered on and the GNSS software starts, if the antenna detection algorithm is enabled, the software starts with Front End initialization and configuration in order to put SENSE_EN bit ON and to enable Antenna Sensing feature.

Then the ANT_EN GPIO is configured: it has to be configured this GPIO direction as output and the signal level as HIGH.

The antenna sensing algorithm checks, at NMEA message rate, if the antenna is correctly connected and detected or, otherwise, it is open or there is a short. At NMEA message output rate (by default 1 Hz) the Antenna Sensing SW reads the SENSE1 and SENSE0 bits level. According to the values reported in the tables 3 and 4, if the SENSE1 and SENSE0 bits are respectively 0 and 1 then the algorithm assumes that the antenna is working properly. If the SENSE1 and SENSE0 levels are both at 0 then the algorithm assumes that the external antenna is not connected; otherwise, if SENSE1 and SENSE0 are both at 1 then the Antenna is considered shorted. In this last case the SW implements the switch off of the Antenna

Summarizing the Antenna Detection with Switch OFF mode enabled:

Step 1 -> Insert External Antenna

Step 2 -> RF Antenna Sensing enabling and GPIO configuration: Teseo3 drives ANT_EN GPIO to enable Antenna Diagnosis and to enable power to External Antenna

Step 3 -> Read SENSE1 and SENSE0

Step 4 -> Check EXTERNAL ANT Condition on Table 3 or Table 4 condition:

1. SENSE1 and SENSE0 levels are respectively 0 and 1: **External Antenna connected and working normally**
2. SENSE1 and SENSE0 values are both 0: **External Antenna OPEN**
3. SENSE1 and SENSE0 values are both 1: **External Antenna Short**

Step 5 -> Report Antenna Status on NMEA message:

1. ANTENNA Status NORMAL
2. ANTENNA Status OPEN
3. ANTENNA Status SHORT

Step 6 -> Switch OFF External Antenna: if a SHORT condition is detected on the External Antenna, Teseo3 drives ANT_EN GPIO to manage the switch off of the antenna.

The syntax of the NMEA message sent is:

$PSTMANTENNASTATUS, <status>

Where status values are:

- 0 -> NORMAL (antenna is working normally)
- 1 -> OPEN
- 2 -> SHORT

The NMEA output message task can update the Antenna Status continuously or only if a change in the external antenna status occurs. The user can configure the possibility to have a periodic message (@NMEA output massage rate) or a message only if the status changes.

The following figure shows the flow diagram for Teseo3 Antenna Detection algorithm (RF and GPIO mode).

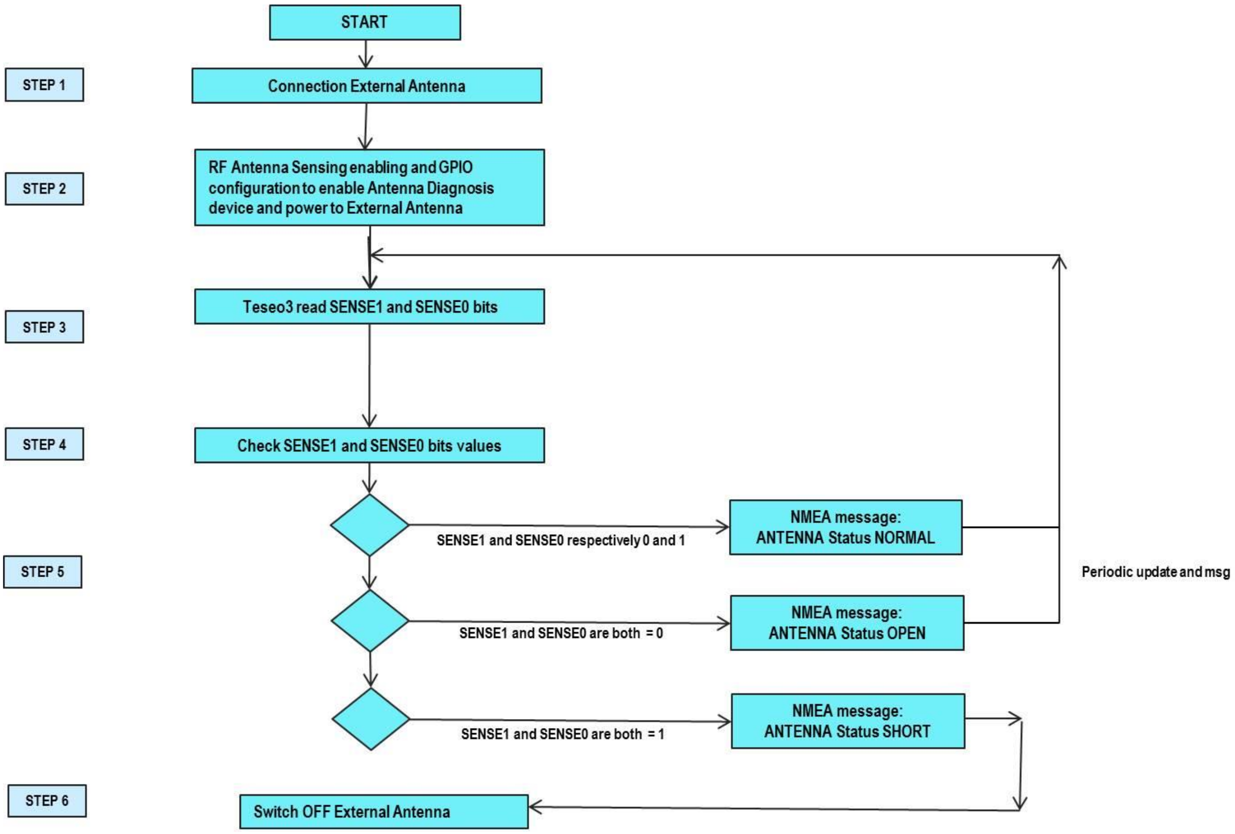


Figure 3: Flow Diagram for Teseo3 Antenna Detection Algorithm (RF and GPIO mode)

5.2 ADC Antenna Sensing mode

5.2.1 Hardware Overview

The figure 1 shows a possible HW schema of the board that can be implemented for the antenna detection.

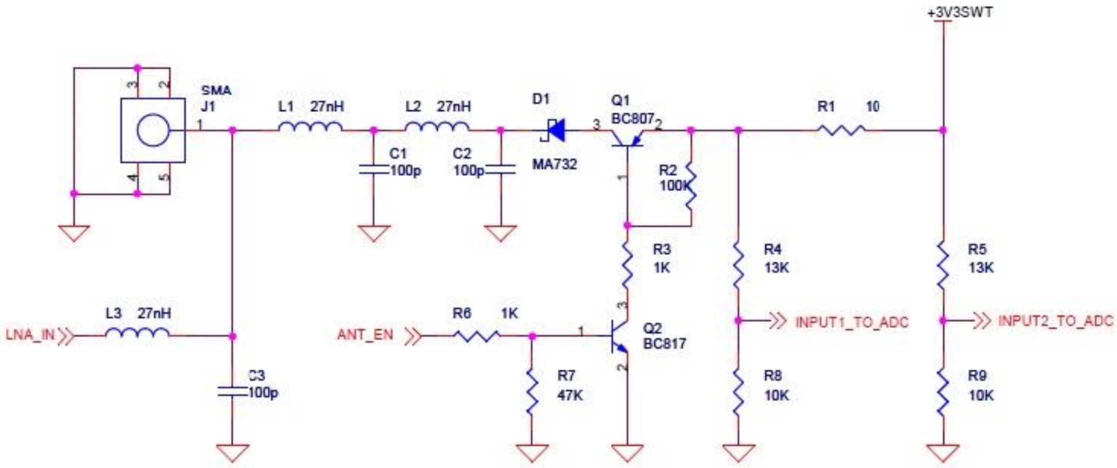


Figure 4: HW schematic for Antenna Detection

Teseo3 reads the voltage at the R1 resistor ends (suggested 10 Ω) by two analog inputs INPUT1 and INPUT2 and send this value to a specific ADC converter input port (default analog inputs are AIN0 and AIN1). A differential measurement is performed and according to the defined voltage level it is possible to detect if short/open/normal current flows through R1 resistor. The application software on top may set a GPIO pin to control the voltage on the antenna.

In the example if GPIO (ANT_EN) is HIGH both transistors Q1 and Q2 are switched ON then the external antenna is supplied by VANT. Otherwise when GPIO (ANT_EN) is LOW both Q1 and Q2 are OFF then the external antenna is disabled.

Note:

1. C1, C2 and L2 are optional; this filter has been added to make the schematic flexible to different application requirements.
2. Teseo3 ADC accepts in input as maximum value 1.4 V, so the voltage from the antenna has to be properly partitioned. This application note and related antenna sensing software are dimensioned assuming an antenna powered with 3.3 V and with a partitioned maximum input voltage to ADC of 1.4 V. The software checks if the antenna is connected comparing the voltage drop at the resistor ends with two thresholds. The minimum and maximum thresholds take into account the scale factor required to go down from 3.3 V to 1.4 V (maximum input voltage to ADC): 1.4/3.3 = 0.42.
3. If a different antenna is used the partitioning has to be reviewed in order to ensure the same ratio.

5.2.2 Software Implementation

When Teseo3 is powered on and the GNSS software starts, if the antenna detection algorithm is enabled as ADC mode, the ADC peripheral is configured and the ADC conversion started.

The software is configurable. It can be enabled or not and, if the Antenna Sensing is enabled as ADC mode, different parameters can be configured:

- The ADC inputs to read from for the Antenna Detection calculations
- The ADC sampling rate
- The values of the minimum and maximum thresholds.

The antenna sensing algorithm checks, at NMEA message rate, if the antenna is correctly connected and detected or, otherwise, if it is open or if there is a short. At NMEA message output rate (by default 1 Hz) the Antenna Sensing software, enabled as ADC mode, read the analog inputs, INPUT1 and INPUT2, to a specific ADC converter input port (by default AIN0 and AIN1, but this analog inputs can be configured differently by the user) in order to measure the current flowing through R1 (10 Ω) resistor. The software performs the differential measurement of the read voltages at the ends of R1 and update the Antenna Status.

If the differential voltage is between 150 mV (default minimum value of the threshold) and 500 mV (default maximum value of the threshold), the algorithm assumes that the antenna is working properly. In this case the default thresholds values are based on the assumption of a current consumption of the antenna between 15 mA and 50 mA. If the differential measurement is less than 150 mV then the antenna is not detected (open) otherwise, if the differential measurement of voltage is greater than 500 mV, then the antenna is considered shorted. Both the thresholds (minimum and maximum) may be configured with different values according to customers' needs and implementation.

It is important to consider that the thresholds have to be configured taking into account that the voltage at ADC input doesn't have to exceed 1.4 V (to avoid saturation). Assuming the power to the antenna is V_{ANT} and the voltage that the customer would like to have at ADC input is V_{ADCIN} (max value 1.4V), the threshold minimum value, $THRSHOLD_{MIN}$, has to be properly scaled in order to have the right threshold to be considered for the comparison:

$THRSCALED_{MIN} = (THRSHOLD_{MIN} * V_{ADCIN}) / V_{ANT}$

and the same for the threshold maximum value:

$THRSCALED_{MAX} = (THRSHOLD_{MAX} * V_{ADCIN}) / V_{ANT}$

In our system we have V_{ADCIN} = 1.4V and V_{ANT} = 3.3V so that

$THRSCALED_{MIN} \sim= 63$ and $THRSCALED_{MAX} \sim= 210$ as default values.

A NMEA sentence reports the status of the Antenna:

- **NORMAL**
- **OPEN**
- **SHORT**

The syntax of the NMEA message sent is:

$PSTMANTENNASTATUS, <status>

Where status values are:

- 0 -> NORMAL (antenna is working normally)
- 1 -> OPEN
- 2 -> SHORT

The following figure shows the flow diagram for Teseo3 Antenna Detection algorithm (ADC mode). In the figure below the default ADC input has been considered, the user can configure different inputs for the Antenna Sensing only for STA8090EXG device.

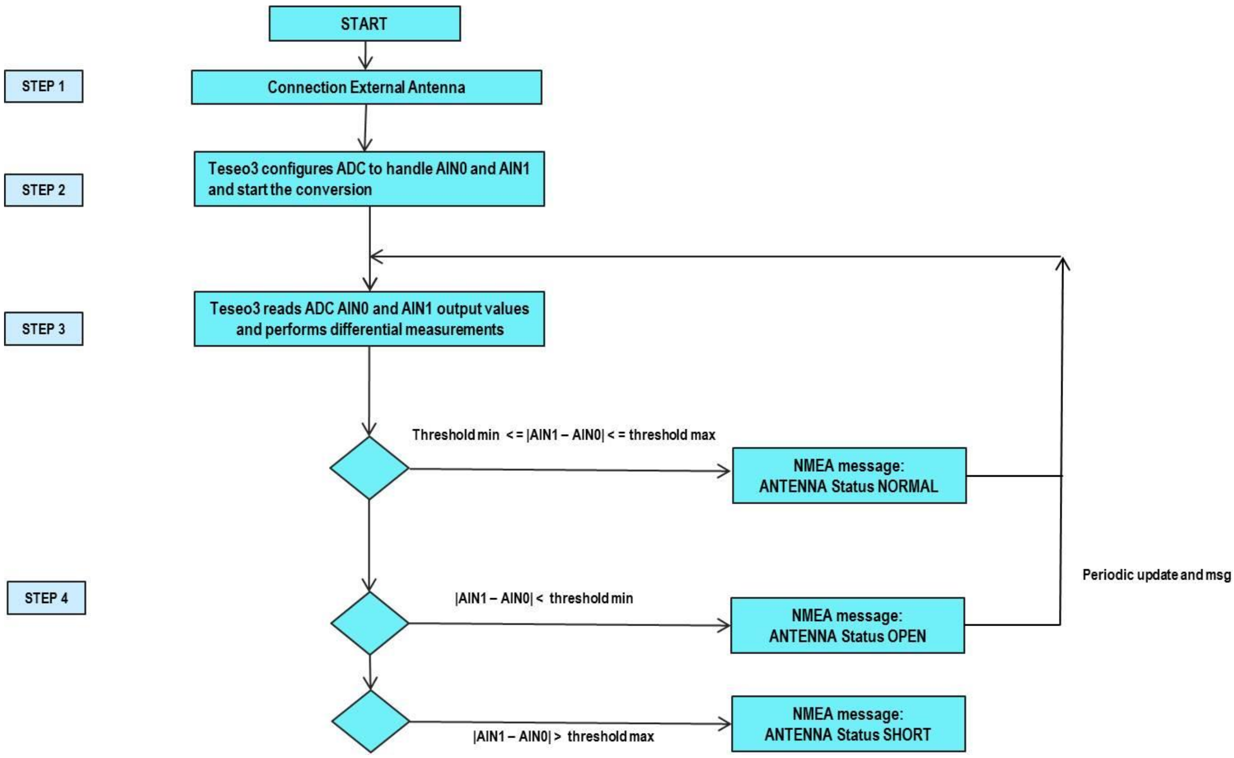


Figure 5: Flow Diagram for Teseo3 Antenna Detection Algorithm (ADC mode)

Note:

1. When Antenna Status detected is SHORT only the NMEA warning output message is sent. The customer antenna sensing application on top, based on the received information, may set GPIO in order to switch off the power to the antenna. It means that, when ADC mode is enabled, the switch off of the external antenna MUST be DISABLED.
2. The ADC inputs reported in the flow diagram are default values. The customer can choose different ADC inputs according the device used.

5.3 GPIO Antenna Sensing mode

5.3.1 Software Implementation

When Teseo3 is powered on and the GNSS software starts, if the antenna detection algorithm is enabled as GPIO mode, four GPIOs, two inputs and two outputs are configured. The user can configure for each GPIO the IDs, the operating control mode and the active level.

The Antenna Detection algorithm, enabled as GPIO mode, as first step configures the operating control mode for the GPIOs and the direction for the GPIOs. The control mode is configurable, the GPIOs direction is fixed:

- ANT_DIG_ON: output from Teseo3 to enable normal operating for antenna diagnosis device and the reading of GPIO SHORT and OPEN signals in input
- ANT_SWITCH_CTRL: output from Teseo3 to manage the power to external antenna
- EXT_ANT_DIG_SHORT: input to Teseo3 to detect if there is a short
- EXT_ANT_DIG_OPEN: input to Teseo3 to detect if the external antenna is open

If the antenna switching is enabled the software sets the pin state for the output GPIOs according to the active level configured by the user. This allows enabling the reading of the OPEN and SHORT pin input signals and the power to external antenna.

The antenna sensing algorithm checks, at NMEA message rate, if the antenna is correctly connected and detected or, otherwise, it is open or there is a short. At NMEA message output rate (by default 1 Hz) the Antenna Sensing software, if enabled as GPIO mode, read the EXT_ANT_DIG_SHORT and the EXT_ANT_DIG_OPEN pins level. If these levels are different respect to the active levels configured, the algorithm assumes that the antenna is working properly. If the SHORT or OPEN signals levels are detected equal to the active levels configured by the user, the algorithm assumes that the external antenna is respectively shorted or not connected.

Summarizing the Antenna Detection (GPIO mode) with Switch OFF mode enabled:

Step 1 -> Insert External Antenna

Step 2 -> GPIO settings: Teseo3 drives ANT_DIG_ON and ANT_SWITCH_CTRL to enable normal operating mode for Antenna Diagnosis device and to enable power to External Antenna

Step 3 -> Read Output Ant Diagnosis Device condition: Teseo3 reads GPIO input signals EXT_ANT_DIG_SHORT and EXT_ANT_DIG_OPEN

Step 4 -> Check EXTERNAL ANT Condition:

1. EXT_ANT_DIG_SHORT and the EXT_ANT_DIG_OPEN pins level are both different from active levels configured: **External Antenna connected and working normally**
2. EXT_ANT_DIG_OPEN value is equal to the active level configured: **External Antenna OPEN**
3. EXT_ANT_DIG_SHORT value is equal to the active level configured: **External Antenna Short**

Step 5 -> Report Antenna Status on NMEA message:

1. ANTENNA Status NORMAL
2. ANTENNA Status OPEN

3. ANTENNA Status SHORT

Step 6 -> Switch OFF External Antenna: if a SHORT condition is detected on the External Antenna, Teseo3 drives ANT_DIG_ON and ANT_SWITCH_CTRL GPIOs to manage the switch off of the antenna.

The syntax of the NMEA message sent is:

$PSTMANTENNASTATUS, <status>

Where status values are:

- 0 -> NORMAL (antenna is working normally)
- 1 -> OPEN
- 2 -> SHORT

The following figure shows the flow diagram for Teseo3 Antenna Detection algorithm (GPIO mode):

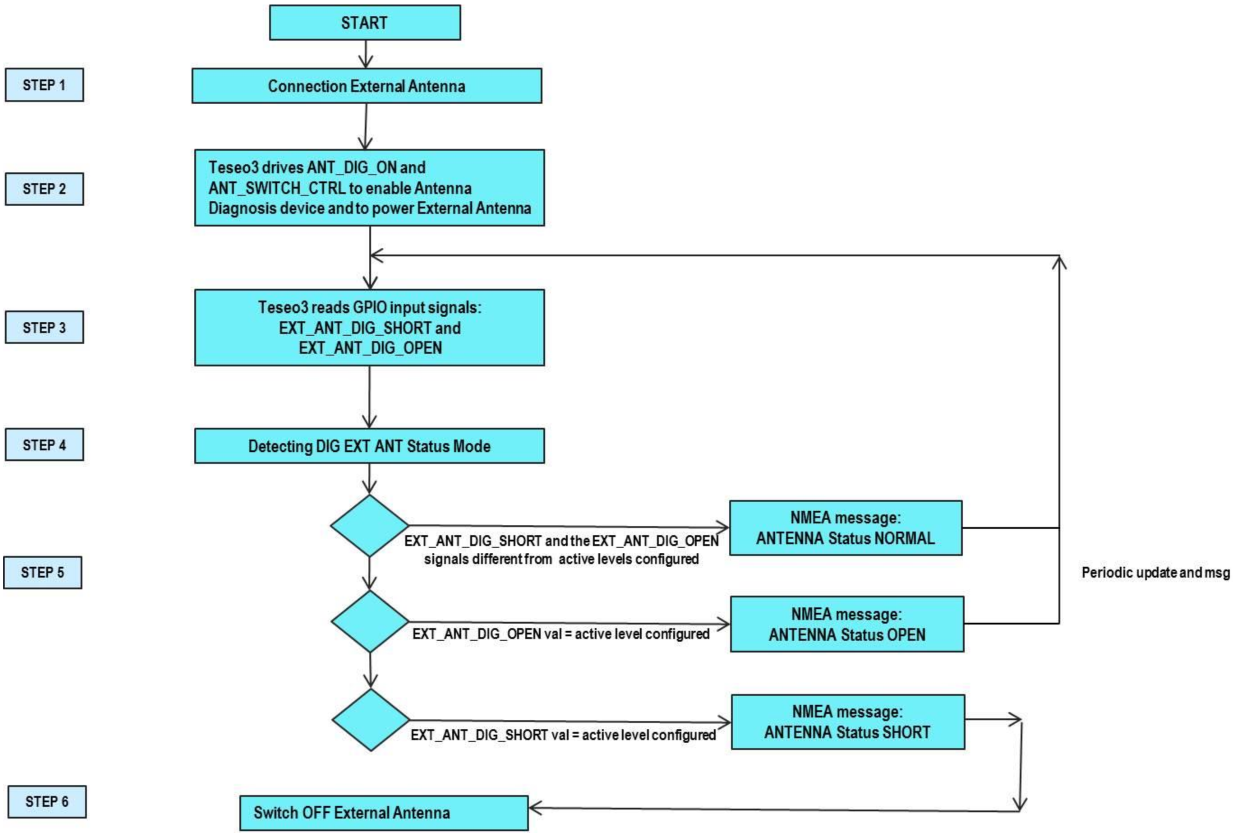


Figure 6: Flow Diagram for Teseo3 Antenna Detection Algorithm (GPIO mode)

5.4 ADC channels reading

To check the status of the antenna another possible method is to read directly via ADC the input channel data reporting the voltage value drop on the resistor.

According to the Teseo3 device selected, there is a possibility to read all the ADC channels via NMEA sentence. This feature may be enabled or not and gives the user the possibility to configure the channels mask (in order to choose the required ADC inputs to read) and the ADC sampling rate (by default the ADC sampling rate is 13 MHz). Following the ADC NMEA sentence, reporting the ADC channels data read, is described:

$PSTMADCDATA,<ADC1>,<ADC2>,<ADC3>,<ADC4>,<ADC5>,<ADC6>,<ADC7>,<ADC8>

Where ADC*i* is a decimal value between 0...1023 that is the ADC data read for the channel *i*.

These values represent the converted voltages values of the ADC channels. They must be converted in Volts to be compared to the thresholds.

The formula that must be used to convert the raw data from the ADC to a value in Volt is:

ADC_out[V] = ADC_out_read * 1.4/1023.

Example:

Considering that the antenna voltage is 3.3 V the maximum input voltage to ADC after partitioning should not exceed 1.4 V, so a scaling factor has to be considered for this purpose. In our system it has 1.4/3.3 = 0.42

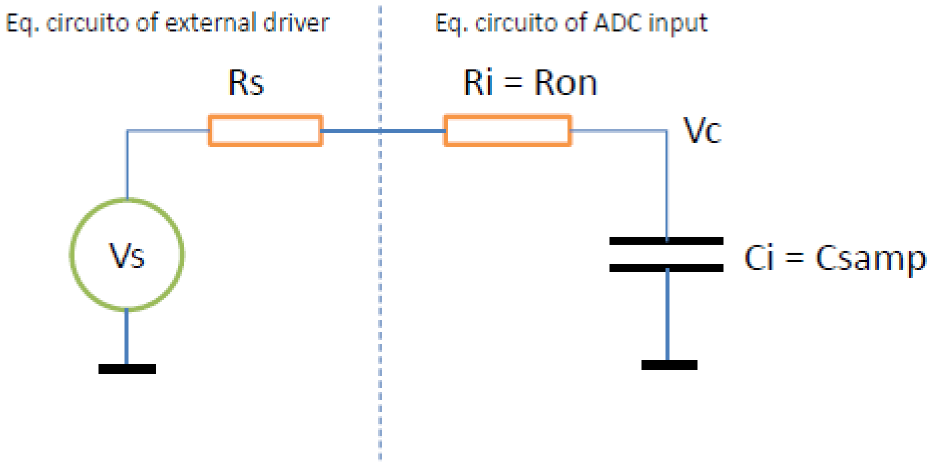
ADC1 = 1.4 Volt read in ADC channels with the value AIN1 ~= 1000

If the Voltage Drop on the resistor in series to the antenna power is 250 mV (25 mA *10 Ω) on the ADC2 channel the read value is

ADC2 = 1.28 Volt-> read in ADC channel reported AIN2 ~= 935

6 ADC Equivalent Circuit

Here below the equivalent circuit of the ADC.



When a step of amplitude Vs is applied, the voltage Vc across the capacitor is:

$$Vc = Vs\ (\ 1-\exp(-t/\tau)\ )\ (1)$$

τ = (Rs+Ri)*Ci = time constant.

Rs = source equivalent resistance

Ri = Ron = ADC input resistance

Ci = input capacitance

At the end of the sampling time Ts, voltage Vc will have reached the source value Vs with an error εVs.

$$Vc(t=Ts) = Vs - \varepsilon\ Vs = Vs\ (1-\varepsilon) \qquad (2)$$

From eq. (1): $Vc(t=Ts)= Vs\ (1-\varepsilon) = Vs\ (\ 1-\exp(-Ts/\tau)\ ) \qquad (3)$

For the present analysis we can assume Vc is approaching Vs to within (1/16)LSB; therefore ε is given by: $\varepsilon = 1/(2^{(N+4)}) = 1/16384$ with N=10 the ADC bit number

Solving eq. 3 for τ:

$$\tau = (Rs+Ri)*Ci = Ts/\ln(16384) = Ts\ /\ 9.7\ (4)$$

From eq. (4), the source resistance is given by:

$$\mathbf{Rs = Ts/(9.7*Ci) - Ri \quad (5)}$$

Using ADC max value, we have: Ci(max) = 8pf; Ri(max) = 2.5KOhm Ts = 210ns (continuous conversion mode)

The maximum source resistance that can be allowed to guarantee an error within (1/16)LSB is:

$$\mathbf{Rs(max) = 210 / (9.7 * 8) - 2.5 = 0.2\ Kohm}$$

Using typical value given in ADC spec with Ci(typ) = 6.4pF and Ri(typ) = 2KOhm

$$\mathbf{Rs(typ) = 210 / (9.7 * 6.4) - 2 = 1.38\ Kohm}$$

7 Antenna Detection FW configuration

The Firmware has to be configured to activate the Antenna Sensing. There are different parameters to be configured according to specific diagnostic mode.

7.1 CDB-ID 228

In order to get the NMEA Antenna Status output sentence, $PSTMANTENNASTATUS has to be enabled in CDB-ID 228, which is the configuration parameter for the "Message List 0" (upper 32 bits).

31															16	15							8	7			4	3		1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
0				0				0				0				2				0				1				8			

CDB-ID 228 Bit 4 value = 1 enable **$PSTMANTENNASTATUS**

The parameter has to be configured as:

- **228 -- > 10**

In order to get the NMEA ADC data message, $PSTMADCDATA has to be enabled in CDB-ID 228 as follow:

CDB-ID 228 Bit 3 value = 1 enable **$PSTMADCDATA**

The parameter has to be configured as:

- **228 -- > 8**

In case other messages in the Message List 0 are enabled this value may deviate from the suggested value. Each message that is enabled will result in the corresponding bit being a "1" instead of a "0".

Regarding the "Message List" usage please refer to the document "STA8089-8090 Firmware Configuration" for TESEO III and "STA8088 Firmware Configuration" for TESEO II.

7.2 CDB-ID 226

This CDB-ID allows the configuration of Antenna Sensing parameters.

31	21 16 15 12	11 8 7	3	2	1 0
Maximum Threshold value (mV) for ADC mode	**Minimum Threshold value (mV) for ADC mode**	**Clk divisor factor to configure ADC sampling rate**	**Switch off enabling bit**	**Periodic Status report**	**Ant Sens on/off and mode sel**

CDB-ID 226 Bit [1:0]	Antenna Sensing mode
0	Antenna Sensing OFF
1	RF MODE
2	ADC mode
3	GPIO mode

CDB-ID 226	Bit 2	value = 1	Periodic Status Reporting ON
CDB-ID 226	Bit 3	value = 1	Antenna switching capability ON
CDB-ID 226	Bit [11:4]	default value = 1	Clk divisor factor (ADC mode)
CDB-ID 226	Bit [12:22]	default value = 0x3F	Min Threshold value for ADC mode
CDB-ID 226	Bit [22:32]	default value = 0xD2	Max Threshold value for ADC mode

Example of antenna sensing configuration:

A. **Antenna Sensing RF mode ON, periodic message ON, switch off enabled**
   - 228 -- > 10
   - 226 -- > 3483F01D

B. **Antenna Sensing RF mode ON, periodic message ON, switch off disabled**
   - 228 -- > 10
   - 226 -- > 3483F015

C. **Antenna Sensing RF mode ON, periodic message OFF, switch off disabled**
   - 228 -- > 10
   - 226 -- > 3483F011

D. **Antenna Sensing ADC mode, periodic message ON, switch off disabled**
   - 228 -- > 10
   - 226 -- > 3483F016

E. **Antenna Sensing GPIO mode, periodic message ON, switch off enabled**
   - 228 -- > 10
   - 226 -- > 3483F01F

7.3 CDB-ID 242

Allow GPIO pin configuration for the antenna detection GPIO mode.

7.4 CDB-ID 243

Allow GPIO mode configuration for the antenna detection GPIO mode

7.5 CDB-ID 244

Allow GPIO active levels configuration for the antenna detection GPIO mode.

7.6 CDB-ID 252

Allow setting the ADC inputs for the antenna sensing feature (ADC mode).

NOTE: The configurability of ADC input is allowed only for STA8090EXG. For other packages the default ADC input configuration must be used. Default ADC input values are: AIN0 and AIN1.

unused																															
31															16	15							8	7						1	0
																														1	1
0				0				0				0				0				0				0				3			

ADC channel input mask. The bit position represents the ADC channel. The selected channel must have the corresponding bit enabled in the mask.

Any combination of couples of channels is allowed only for STA8090EXG. For all other packages default value must be used: 0x3.

CDB-ID 252 Bit [11:4] default value = 3 AIN0 and AIN1

7.7 CDB-ID 225

This parameter is a 17 Bit value with the following bit fields:

unused															Clk divide for sampling								Channel Mask								
31															16	15							8	7							0
															0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1
0				0				0				0				0				1				0				7			

CDB-ID 225	Bit0	value = 1	ADC channels data read ON
CDB-ID 225	Bit [8:1]	value = 0000.0011	Mask to enable AIN0 and AIN1
CDB_ID 225	Bit [16:9]	value = 1	clock divided by 1

In this case parameter has to be configured as:

- **225 -- > 107**

Otherwise, if the user chooses to enable all ADC channels this parameter has to be configured as:

- **225 -- > 3FF**

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