Sendyne®

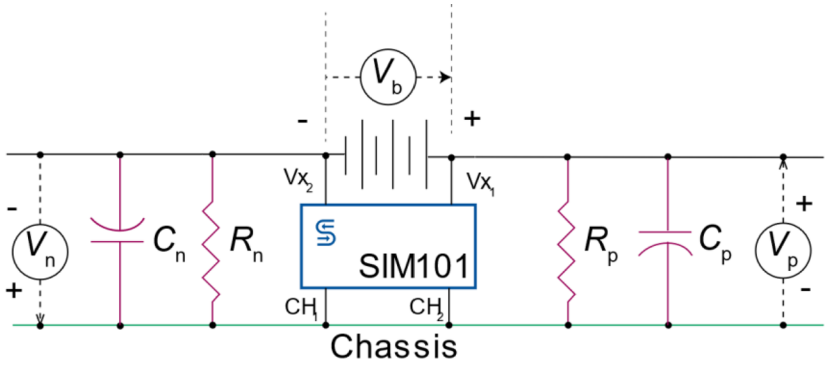
SIM101 CAN Protocol Reference Manual

VERSION: 2.3

Sendyne SIM101 CAN Protocol Implementation

Features

- CAN 2.0B extended frame format
- 500 kbit/s or 250 kbit/s



SIM101 isolation monitoring reference diagram

Release information

Version 2.0 of the CAN protocol is supported by SIM101 firmware V2.0 and later. Main characteristics of V2.0 are:

- Fixed DLC=3 (Data Length Code) for all messages originating from the host
- Introduction of new signals and messages
- Introduction of safe maintenance mode for setting among others CAN message IDs, CAN speed and IT system monitoring parameters
- Backwards compatibility with CAN protocol version 0.8a

How to read this document

Throughout this document new entries since v0.8a are emphasized by grey background. Obsolete signals and messages have been greyed out.

General message format

The Sendyne SIM101 communicates with the host system through a command-response protocol. Communications are initiated by the host issuing a message with extended default ID 0xA100101, followed by a one- byte multiplexor (`Request_mux`) indicating the type of operation (read, write or command) to be performed. Undefined message bytes are ignored.

Request from Host:

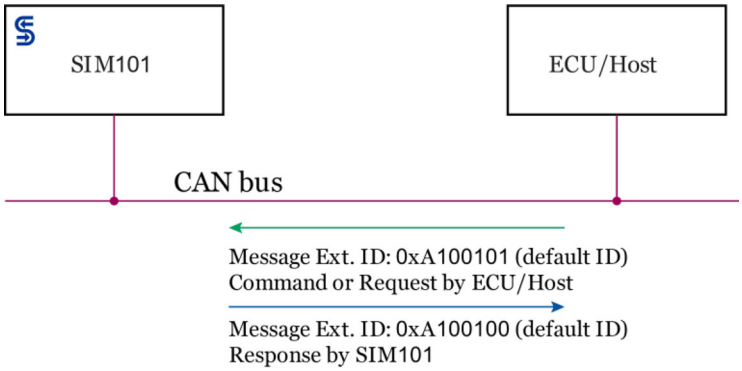
Ext. ID	byte 0	byte 1	byte 2

0xA100101	Request_mux	Data	Data

If the multiplex value Request_mux specifies a request for reading a signal, the SIM101 will respond with Ext. ID 0xA100100 followed by a multiplexer byte OpCode_mux with the same value as the multiplexer of the request message and any data pertinent to the transaction. If the value of Request_mux specifies a command the SIM101 will execute the command.

SIM101 response:

Ext. ID	byte 0	byte 1	byte 2
0xA100100	OpCode_mux		



Data types

SIM101 data can have the length of a bit, byte, 2-bytes or 4-bytes depending on the content of the transaction. The data types can be a flag, an ASCII character, a signed or an unsigned integer; they are documented in each signal description. All signed integers are encoded using 2's complement.

Signals and Signal Groups

Data communicated in messages are defined as signals. A signal can be a flag, ASCII characters, a signed or an unsigned integer. They are defined in the signal section of this document. Signal groups consist of a collection of signals defined in the signal groups section of this document. Signals and signal group names are represented with a blue Courier font in this document.

Byte ordering

In case of multi-byte data the order of bytes within each message is specified in signal definition as a big endian (Motorola) or little endian (Intel).

Big endian (MOTOROLA) data bytes order

byte n	byte n+1	byte n+2	byte n+3
MSB	Data	Data	LSB

Little endian (INTEL) data bytes order

byte n	byte n+1	byte n+2	byte n+3
LSB	Data	Data	MSB

Host message multiplexer

In a host originating message byte 0 is the multiplexor specifying the type of operation (read, write or command).

Requests from the host to the SIM101

Ext. ID	byte 0	byte 1	byte 2
0xA100101	`Request_mux`	Data	Data

Host request multiplexer values

The following table lists the valid `Request_mux` values:

`SIM101_Request_mux`

Value	*Name*	*Data bytes*	*Description*
0x01	Request Part name 0	2	Request signal `Part_name_0`
0x02	Request Part name 1	2	Request signal `Part_name_1`
0x03	Request Part name 2	2	Request signal `Part_name_2`
0x04	Request Part name 3	2	Request signal `Part_name_3`
0x05	Request Version 0	2	Request signal `Version_0`
0x06	Request Version 1	2	Request signal `Version_1`
0x07	Request Version 2	2	Request signal `Version_2`
0x08	Request Serial number 0	2	Request signal `Serial_number_0`
0x09	Request Serial number 1	2	Request signal `Serial_number_1`
0x0A	Request Serial number 2	2	Request signal `Serial_number_2`
0x0B	Request Serial number 3	2	Request signal `Serial_number_3`
0x0C	Request Uptime counter	2	Request signal `Uptime_counter`
0x60	Request Vn high resolution	2	Request signal `Vn_hi_res`
0x61	Request Vp high resolution	2	Request signal `Vp_hi_res`
0x62	Request Vexc high resolution	2	Request signal `Vexc_hi_res`
0x63	Request Vb high resolution	2	Request signal `Vb_hi_res`
0x65	Request Vpwr high resolution	2	Request signal `Vpwr_hi_res`
0x80	Request Temperature	2	Request signal `Temperature`
0xC1	Command to SIM101	2	Action determined by the values of data bytes: *byte1* *byte2* *Action* 0x01 0x23 Reset 0xEC 0x00 Disable excitation signal 0xEC 0x01 Lock excitation signal high 0xEC 0x02 Lock excitation signal low
0xE0	Request Isolation state	2	Request signal group ≈`isolation_state`

0xE1	Request Isolation resistances	2	Request signal group ≈`isolation_resistances`
0xE2	Request Isolation capacitances	2	Request signal group ≈`isolation_capacitances`
0xE3	Request Voltages *V*p and *V*n	2	Request signal group ≈`voltages_Vp_and_Vn`
0xE4	Request Battery voltage *V*b	2	Request signal group ≈`battery_voltage`
0xE5	Request Error flags	2	Request signal group ≈`Error_flags`
0xE6	Request dynamic capacitance energy state	2	Request signal group ≈`safety_touch_energy`
0xE7	Request dynamic isolation state	2	Request signal group ≈`Safety_touch_current`
0xF0	Read max battery design voltage	2	Request signal `Vb_max`

SIM101 response multiplexer values

A message from SIM101 is always transmitted as a response to a message from the host. Byte 0 of SIM101 messages is the `OpCode_mux` multiplexer of the message. Its value is the same value as the host's message multiplexer.

Responses from SIM101 to host

Ext. ID	byte 0	byte 1	byte 2	...
0xA100100	`OpCode_mux`	Data	Data	...

The following table lists the valid `OpCode_mux` values in SIM101 responses. Signals preceded with a double tilde (≈) symbol represent signal groups (a collection of signals) which are defined later in this document.

`OpCode_mux`

Value	*Name*	*Data bytes*	*Signals (~) and signal groups (≈)*
Manufacturer's data			
0x01	Part name 0	4	`~Part_name_0`
0x02	Part name 1	4	`~Part_name_1`
0x03	Part name 2	4	`~Part_name_2`
0x04	Part name 3	4	`~Part_name_3`
0x05	Version 0	4	`~Version_0`
0x06	Version 1	4	`~Version_1`
0x07	Version 2	4	`~Version_2`
0x08	Serial number 0	4	`~Serial_number_0`
0x09	Serial number 1	4	`~Serial_number_1`
0x0A	Serial number 2	4	`~Serial_number_2`
0x0B	Serial number 3	4	`~Serial_number_3`
Diagnostic			
0x0C	Uptime counter	4	`~Uptime_counter`
Measurements			
0x60	Vn high resolution	4	`~Vn_hi_res`
0x61	Vp high resolution	4	`~Vp_hi_res`
0x62	Vexc high resolution	4	`~Vexc_hi_res`
0x63	Vb high resolution	4	`~Vb_hi_res`
0x65	Vpwr high resolution	4	`~Vpwr_hi_res`
Environmental			
0x80	Temperature	4	`~Temperature`
Isolation state			
0xE0	Isolation state	7	`≈Status_bits + ≈isolation_state`
0xE1	Isolation resistances	7	`≈Status_bits + ≈isolation_resistances`
0xE2	Isolation capacitances	7	`≈Status_bits + ≈isolation_capacitances`
0xE3	Voltages Vp and Vn	7	`≈Status_bits + ≈voltages_Vp_and_Vn`
0xE4	Battery voltage Vb	7	`≈Status_bits + ≈battery_voltage`
0xE5	Error flags	3	`≈Status_bits + ≈Error_flags`

0xE6	Safety touch energy	7	≈Status_bits + ≈safety_touch_energy
0xE7	Safety touch current	7	≈Status_bits + ≈safety_touch_current
0xF0	Max battery design voltage	2	~Max_battery_working_voltage

SIM101 signals

The following table defines the available signals of SIM101.

SIM101 signals

Signal Name	*Length [Bits]*	*Byte Order*	*Value Type*	*Unit*	*Value Table*	*Comment*
Cn	16	M	U	nF	-	Estimated value of capacitances Cn.
Cn_uncertainty	8	M	U	%	-	Cn estimate uncertainty expressed in %
Cp	16	M	U	nF	-	Estimated values of capacitance Cp.
Cp_uncertainty	8	M	U	%	-	Cp estimate uncertainty expressed in %
Ct	16	M	U	nF	-	Estimated value of total capacitance
Ct_uncertainty	8	M	U	%	-	Ct estimate uncertainty expressed in %
Electrical_isolation	16	M	U	Ω/V	-	Minimum resistance per Volt isolation path between the IT system and the chassis. The value is calculated based on the battery's Vb_max Voltage.
Electrical_isolation_uncertainty	8	M	U	%	-	Electrical isolation uncertainty expressed in %
Energy_stored	16	M	U	mJ	-	This is the maximum energy that can be stored in the Y capacitors between the battery and chassis at the maximum working voltage.
Energy_stored_uncertainty	8	M	U	%	-	Energy stored uncertainty expressed in %
Err_CH	1	-	B		-	0 - CH1 and CH2 (chassis) connections are good 1 - Connection to chassis broken.
Err_Clock	1	-	B			0 – No timing errors 1 – SIM101 clock error
Err_Vexi	1	-	B		-	0 - Excitation voltage level is correct 1 – Excitation voltage level out of range
Err_Vpwr	1	-	B		-	0 - Power supply level is good 1 – Power supply level out of range
Err_Vx1	1	-	B		-	0 - VX1 connection is good (SIM101 to battery positive terminal connection) 1 – VX1 connection broken
Err_Vx2	1	-	B		-	0 - VX2 connection is good (SIM101 to battery negative terminal connection) 1 – VX2 connection broken
Err_VxR	1	-	B		-	0 - VX1 and VX2 connections are correct

Signal Name	*Length [Bits]*	*Byte Order*	*Value Type*	*Unit*	*Value Table*	*Comment*
						1 – VX1 and VX2 connections are reversed
Err_Watchdog	1	-	B			0 – No watchdog error 1 – Watchdog error
Err_Temp	1	-	B			0 – Temperature normal 1 – Temperature higher than 105 C
Exc_off	1	-	B			0 – Excitation pulse operating 1 – Excitation pulse is turned off
Excitation_pulse_off	32	M	U		*	Sending data 0xDEADBE1F with SIM_Request_mux = 0x62 disables the excitation pulse of the SIM101. In order to re-enable it a Restart message has to be sent.
Hardware_Error	1	-	B		-	0 – No hardware error 1 – A hardware error was detected
High_Battery_Voltage	1	-	B		-	0 – Observed battery voltage is less than the programmed Max_battery_working_voltage value 1 – Observed battery voltage is higher than Max_battery_working_voltage
High_Uncertainty	1	-	B		-	0 – Uncertainty of calculated values is less than 5% 1 – Uncertainty is higher than 5%
Isolation_status_bits	2	-	B		-	00 – Isolation status OK 10 – Warning 11 - Fault
Low_Battery_Voltage	1	-	B		-	0 – Observed battery voltage higher than 15 V 1 – Observed battery voltage less than 15 V
Max_battery_ working_voltage	16	M	U	V	-	Maximum battery operating voltage (in Volts) written to Vb_max
No_New_Estimates	1	M	U		-	0 – The flag is zero when new and unread isolation values have been calculated 1 – No new estimates
Part_name0	32	-	A		-	The first ASCII characters of part name 1/4
Part_name_1	32	-	A		-	ASCII representation of part name 2/4
Part_name_2	32	-	A		-	ASCII representation of part name 3/4
Part_name_3	32	-	A		-	ASCII representation of part name 4/4
Restart	32	M	U		*	Signal to restart the operation of SIM101. Use data value 0x01234567.
Rn	16	M	U	kΩ	-	Estimate of total resistance between negative rail and chassis
Rn_uncertainty	8	M	U	%	-	Rn estimate uncertainty in %
Rp	16	M	U	kΩ	-	Estimate of total resistance between positive rail and chassis
Rp_uncertainty	8	M	U	%	-	Rp estimate uncertainty
Serial_number_0	32	I	U		-	Unit serial number, 1/4
Serial_number_1	32	I	U		-	Unit serial number, 2/4
Serial_number_2	32	I	U		-	Unit serial number, 3/4
Serial_number_3	32	I	U		-	Unit serial number, 4/4

Signal Name	*Length [Bits]*	*Byte Order*	*Value Type*	*Unit*	*Value Table*	*Comment*
Temperature	32	M	S	m°C	-	Temperature in milli Celsius. The temperature is averaged over a 640ms period. The reported value is always the most recent average value.
Touch_energy	16	M	U	mJ	-	Dynamic calculation of capacitive discharge potential energy, based on the actual max(Vp, Vn) rail to chassis voltage and total capacitance. Updated each 4.5 s.
Touch_energy_fault	1		B		-	0 – Capacitive energy stored within limit 1 – Capacitive energy stored exceeds 0.2 J limit
Touch_energy_uncertainty	8	M	U	%	-	Discharge energy uncertainty expressed in %
Touch_isolation	16	M	U	Ω/V	-	Minimum resistance/Volt path, between IT system & chassis. The value is calculated upon the actual operating Vb. Updated each 10 ms.
Touch_isolation_uncertainty	8	M	U	%	-	Uncertainty on estimation of Touch_isolation
Uptime_counter	32	M	U	s	-	The counter is incremented every 10ms.
Vb	16	M	S	V	-	Voltage of the monitored IT power system. The reported value is the average since the last request. The average is updated every 10ms.
Vb_hi_res	32	M	S	µV	-	Reports voltage of monitored IT power system in µV. The reported value is the average since the last request. The average is updated every 10ms.
Vb_max	16	M	U	V	-	Maximum value of IT power supply voltage. It is the maximum between Max_battery_voltage and the maximum actual value recorded by SIM101.
Vb_max_uncertainty	8	M	U	%	-	Vb_max uncertainty in % (if Vb_max is the recorded value)
Vb_uncertainty	8	M	U	%	-	Vb uncertainty in %
Vexc_hi_res	32	M	S	µV	-	Returns the value of the excitation signal in µV. The reported value is the average since the last request. The average is updated every 10ms.
Vpwr_hi_res	32	M	U	µV	-	Value of SIM101 power supply in µV. The reported value is the average since the last request. The average is updated every 10ms.
Vn	16	M	S	V	-	Potential between negative IT system power rail and chassis. Dynamic value includes excitation voltage effect. The reported value is the average since the last request. The average is updated every 10ms.
Vn_uncertainty	8	M	S	%	-	Vn uncertainty in %
Vn_hi_res	32	M	S	µV		Potential between negative IT system power rail and chassis. Dynamic value includes excitation voltage effect. The reported value is the average since the last request. The average is updated every 10ms.
Vp	16	M	S	V	-	Potential between positive IT system power rail and chassis. Dynamic value includes excitation voltage effect. The reported value is the average since the last request. The average is updated every 10ms.
Vp_uncertainty	8	M	S	%	-	Vp uncertainty in %
Vp_hi_res	32	M	S	µV		Potential between positive IT system power rail and chassis. Dynamic value includes excitation voltage effect. The reported

Signal Name	*Length [Bits]*	*Byte Order*	*Value Type*	*Unit*	*Value Table*	*Comment*
						value is the average since the last request. The average is updated every 10ms.

U – unsigned integer
S – signed integer
B – Boolean (encoded as a single bit, 0=False and 1=True)
A – ASCII
M – Motorola byte order (big endian)
I – Intel byte order (little endian)
* - indicates that a value table (data) is associated with the signal

SIM101 signal groups

Status_bits

The Status_bits byte is a collection of signal bits that provides concentrated information for the state of the isolation system as well as of the proper operation of SIM101.

The layout of the signal bits within the Status_bits signal group is shown below:

≈Status_bits

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
HE	EF	HU	EO	HV	LV	IS1	IS0

Status bits

bit	*Symbol*	*Signal*	*Description*
7	HE	Hardware_Error	0 – No hardware error 1 – Hardware error. The host should perform a "Read SIM101 Error Flags" operation in order to resolve the issue
6	EF	Touch_energy_fault	0 – Electrostatic potential energy within limits 1 – Energy exceeds 0.2 J
6	NE	No_New_Estimates	ELIMINATED
5	HU	High_Uncertainty	0 – Uncertainty of calculated values is less than 5% 1 – Uncertainty values are higher than 5%. The uncertainty values always accompany reported data.
4	EO	Exc_off	0 – Excitation pulse operating 1 – Excitation pulse is turned off
3	HV	High_Battery_Voltage	0 – Observed battery voltage is less than the specified Max_battery_working_voltage. 1 – The observed battery voltage value is higher than the specified Max_battery_working_voltage value. The flag will be set if the Max_battery_working_voltage register has not been set, or if the set value is less than the maximum observed battery voltage value. If this flag is set, isolation resistance and stored energy will be calculated based on the maximum observed battery voltage.
2	LV	Low_Battery_Voltage	0 – Observed battery voltage higher than 15 V 1 – Observed battery voltage less than 15 V. This flag is also set when battery is disconnected. When this flag is set SIM101 will report Rp and Rn as the parallel combination of Rp||Rn
1-0	IS1-IS0	Isolation_status_bits	**00** **Isolation status OK** **01** Isolation state unknown. Set when excitation signal is disabled. **10** Warning. Isolation resistance < 500 Ohm/V limit (the 500 Ohm/V value can be changed in the maintenance mode) **11** Isolation fault. Isolation resistance <100 Ohm/V limit (the 100 Ohm/V value can be changed in the maintenance mode)

The following signal groups are defined and used in SIM101 messages

Isolation state

≈isolation_state

Start byte	*Signal*
2	Electrical_isolation
4	Electrical_isolation_uncertainty
5	Energy_stored
7	Energy_stored_uncertainty

Isolation resistances

≈isolation_resistances

Start byte	*Signal*
2	Rp
4	Rp_uncertainty
5	Rn
7	Rn_uncertainty

Isolation capacitances

≈isolation_capacitances

Start byte	*Signal*
2	Cp
4	Cp_uncertainty
5	Cn
7	Cn_uncertainty

Voltages Vp and Vn

≈voltages_Vp_and_Vn

Start byte	*Signal*
2	Vp
4	Vp_uncertainty
5	Vn
7	Vn_uncertainty

Battery voltage

≈battery_voltage

Start byte	*Signal*
2	Vb
4	Vb_uncertainty
5	Vb_max
7	Vb_max_uncertainty

Error flags

The Error_flags byte is a collection of one bit signals which are updated during the continuous self-checking of SIM101. If any of these flags is set, the signal bit Hardware_error in the Status_bits will be set.

≈Error_flags

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	Bit7	Bit 6-0
Err_ Vx2	Err_ Vx1	Err_ CH	Err_ VxR	Err_ Vexi	Err_ Vpwr	Err_ Watchdog	Err_ Clock	Err_ Temp	-

Error flags

Bit	*Symbol*	*Signal*	*Description*
15	V_{X2}	Err_Vx2	0 – V_{X2} connection is good (SIM101 to battery negative terminal) 1 – V_{X2} connection is broken
14	V_{X1}	Err_Vx1	0 – V_{X1} connection is good (SIM101 to battery positive terminal) 1 – V_{X1} connection is broken
13	CH	Err_CH	0 – CH_1 and CH_2 connections are good (chassis connections) 1 – CH_1 or CH_2 connection is broken
12	VxR	Err_VxR	0 – V_{X1} and V_{X2} connection are correct 1 – V_{X1} and V_{X2} connection are reversed
11	V_{EXI}	Err_Vexi	0 – Excitation voltage level is correct 1 – Excitation voltage level is out of specs
10	V_{PWR}	Err_Vpwr	0 – Power supply level is good 1 – Power supply level is out of range
9	WD	Err_Watchdog	0 – No watchdog error 1 – Watchdog error
8	CE	Err_clock	0 – No timing errors 1 – SIM101 clock error
7	HT	Err_temp	0 – Temperature normal 1 – Temperature higher than 105 C

6-0	Undefined	Reserved

Safety touch current

Safety touch current signal group provides dynamic information on touch current safety based on the operating power source voltage and the minimum isolation resistance path among the rails and chassis.

≈safety_touch_current

Start byte	*Signal*
2	Vb
4	Vb_uncertainty
5	Touch_isolation
7	Touch_isolation_uncertainty

Safety touch energy

Safety touch energy signal group provides dynamic information on touch energy safety based on the maximum rail voltage and the total system capacitance.

≈safety_touch_energy

Start byte	*Signal*
2	Touch_energy
4	Touch_energy_uncertainty
5	Ct
7	Ct_uncertainty

Messages

Data requests from host to SIM101

This group consists of single byte messages issued by the host in order to poll the SIM101 for data. The SIM101 will respond to each one of these requests by sending a multiplexed message with the same multiplexer value as the multiplexer of the request followed by the signal group data requested.

Ext. ID	byte 0	byte 1	byte 2
0xA100101	Request_mux		

Request_mux

Value	*Name*	*Data bytes*	*Description*
0x01	Request Part name 0	2	Request signal Part_name_0
0x02	Request Part name 1	2	Request signal Part_name_1
0x03	Request Part name 2	2	Request signal Part_name_2
0x04	Request Part name 3	2	Request signal Part_name_3
0x05	Request Version 0	2	Request signal Version_0
0x06	Request Version 1	2	Request signal Version_1
0x07	Request Version 2	2	Request signal Version_2
0x08	Request Serial number 0	2	Request signal Serial_number_0
0x09	Request Serial number 1	2	Request signal Serial_number_1
0x0A	Request Serial number 2	2	Request signal Serial_number_2
0x0B	Request Serial number 3	2	Request signal Serial_number_3
0x0C	Request Uptime counter	2	Request signal Uptime_counter
0x60	Request Vn high resolution	2	Request signal Vn_hi_res
0x61	Request Vp high resolution	2	Request signal Vp_hi_res
0x62	Request Vexc high resolution	2	Request signal Vexc_hi_res
0x63	Request Vb high resolution	2	Request signal Vb_hi_res
0x65	Request Vpwr high resolution	2	Request signal Vpwr_hi_res
0x80	Request Temperature	2	Request signal Temperature
0xE0	Request Isolation state	2	Request signal group ≈isolation_state
0xE1	Request Isolation resistances	2	Request signal group ≈isolation_resistances
0xE2	Request Isolation capacitances	2	Request signal group ≈isolation_capacitances
0xE3	Request Voltages *V*p and *V*n	2	Request signal group ≈voltages_Vp_and_Vn
0xE4	Request Battery voltage *V*b	2	Request signal group ≈battery_voltage
0xE5	Request Error flags	2	Request signal group ≈Error_flags
0xE6	Request dynamic capacitance energy state	2	Request signal group ≈safety_touch_energy
0xE7	Request dynamic isolation state	2	Request signal group ≈Safety_touch_current
0xF0	Read max battery design voltage	2	Request signal Vb_max

Manufacturer's data requests

Request part name

SIM101 part name consists of 16 ASCII characters. The host can retrieve the part name through four message transactions. Each of the four Part_name_N signals is 32 bits (4 characters) arranged in Intel byte order.

Request_mux	*Name*	*Data bytes*	*Description*
0x01	Request Part name 0	None	Request signal Part_name_0
0x02	Request Part name 1	None	Request signal Part_name_1
0x03	Request Part name 2	None	Request signal Part_name_2
0x04	Request Part name 3	None	Request signal Part_name_3

Request from host:

Ext. ID	Request_mux	byte 1	byte 2
0xA100101	0x0N		

Where N can be 1, 2, 3 or 4

Response from SIM101:

Ext. ID	OpCode_mux	byte 1-4
0xA100101	0x0N	Part_name_(N-1)

Where N can be 1, 2, 3 or 4

The SIM101 part name can be formed by concatenating the four signals

SIM101 Part Name			
Part_name_3	Part_name_2	Part_name_1	Part_name_0

Request firmware version

SIM101 version number consists of 12 ASCII characters. The host can retrieve the version number through three message transactions. Each of the three Version_N signals is 32 bits (4 characters) arranged in Intel byte order.

Request_mux	*Name*	*Data bytes*	*Description*
0x05	Request version 0	None	Request signal Version_0
0x06	Request version 1	None	Request signal Version_1
0x07	Request version 2	None	Request signal Version_2

Request rom host:

Ext. ID	Request_mux
0xA100101	0x0N

Where N can be 5,6, or 7

Response from SIM101:

Ext. ID	OpCode_mux	byte 1-3
0xA100100	0x0N	Version_(N-5)

Where N can be 5,6, or 7

The SIM101 firmware version can be formed by concatenating the three signals

SIM101 Version		
Version _0	Version _1	Version_2

Request serial number

Serial number is unique for every SIM101 MCUs and consists of 128 bits. The host can retrieve the serial number through four message transactions. Each of the four Serial_number_N signals is 32 bits arranged in Intel byte order.

Request_mux	*Name*	*Data bytes*	*Description*
0x08	Request Serial number 0	None	Request signal Serial_number_0
0x09	Request Serial number 1	None	Request signal Serial_number_1
0x0A	Request Serial number 2	None	Request signal Serial_number_2
0x0B	Request Serial number 3	None	Request signal Serial_number_3

Request rom host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x0N	

Where N can be 8, 9, A or B

Response from SIM101:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x0N	Serial_number_(N-8)

Where N can be 8, 9, A or B

The SIM101 serial number can be formed by concatenating the four signals as follows:

SIM101 Serial number			
Serial_number_3	Serial_number_2	Serial_number_1	Serial_number_0

Data reporting requests

Request temperature

SIM101 monitors environmental temperature and can communicate it to the host through the Temperature 32 bit signed integer signal (mCelsius units). The reported value always correspond to an average over 640 ms

and the most recent average value is always returned. The Temperature signal byte order is Motorola (Big endian).

To read Temperature the host sends:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x80	

SIM101 response:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x80	Temperature

Request isolation state

The "Request isolation state" and its response is intended to provide in a single message an overview of the safety state of the isolation system. The "Request isolation state" message of the host is as follows:

Request from Host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE0	

On "Request isolation state" the SIM101 will respond with a message composed of two "signal groups", the ≈Status_bits and ≈isolation_state.

Response from SIM101:

Ext. ID	OpCode_mux	byte 1	bytes 2-7
0xA100100	0xE0	≈Status_bits	≈isolation_state

The ≈Status_bits signal group is a collection of flags described in the "SIM101 signal groups" section of this document. They provide information on whether a warning or fault condition has occurred, on the success or failure of SIM101's self-check, as well as other information related to the quality of the estimates and the voltage conditions of the IT system and should be checked in each communication in order to validate the estimates provided.

The ≈isolation_state signal group provides the following information:

Signal	*Byte#*	*Units*	*Description*
Electrical_isolation	2-3	Ω/V	This value corresponds to the *minimum* resistance path between the positive or negative rail and chassis. It is calculated as: min(Rp, Rn)/Vb_max, where min(Rp, Rn) is the minimum isolation resistance between the positive or negative rail and chassis. If the "warning" or "fault" Isolation_status_bits are set the host should check the ≈isolation_resistances signal group for the presence of a hazardous symmetrical fault.
Electrical_isolation_uncertainty	4	%	Uncertainty of Electrical_isolation estimate
Energy_stored	5-6	mJ	Maximum stored energy at Vb_max in mJ. Energy_stored is calculated as: 0.5 * (Cp+Cn) * Vb_max^2
Energy_stored_uncertainty	7	%	Uncertainty of Energy_stored estimate

Request isolation resistances

The "Request isolation resistances" and its response is intended to provide individual estimates for the isolation resistance values between the positive and negative power rails and the chassis. These values are updated every 10 ms. Besides cross-checking these estimates against pre-programmed fault values, in case of a warning or fault condition, by checking these values the host can determine if there is a symmetrical fault. A symmetrical fault can lead to high temperatures and power loss and unlike single faults is not controllable. The "Request isolation resistances" format is as follows:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE1	

On "Request isolation resistances" the SIM101 will respond with a message composed of two "signal groups", the **≈Status_bits** and **≈isolation_resistances**.

Response from SIM101:

Ext. ID	OpCode_mux	byte 1	Byte 2-7
0xA100100	0xE1	≈Status_bits	≈isolation_resistances

The ≈**Status_bits** signal group is a collection of flags described in the "SIM101 signal groups" section of this document and as with any isolation state related message they should be checked to validate the estimates, the condition of the SIM101 and the presence of any warnings or alerts.

The **≈isolation_resistances** signal group provides the following information:

Signal	*Byte#*	*Units*	*Description*
Rp	2-3	kΩ	Estimate for the total resistance between the positive power rail and chassis
Rp_uncertainty	4	%	Uncertainty of Rp estimate
Rn	5-6	kΩ	Estimate for the total resistance between the negative power rail and chassis
Rn_uncertainty	7	%	Uncertainty of Rn estimate

Request isolation capacitances

The "Request isolation capacitances" message and the SIM101 response is intended to provide individual estimates for the isolation capacitance values between the positive and negative power rails and the chassis. SIM101 utilizes these values to calculate potentially hazardous energy stored. The SIM101 always report the same value for the positive and negative isolation capacitances; this value corresponds to half the total isolation capacitance and is updated every 10 ms. The "Request isolation capacitances" format is as follows:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE2	

On "Request isolation capacitances" the SIM101 will respond with a message composed of two "signal groups", the ≈**Status_bits** and **≈isolation_capacitances**.

SIM101 response:

Ext. ID	OpCode_mux	byte 1	Byte 2-7
0xA100100	0xE2	≈Status_bits	≈isolation_capacitances

The ≈Status_bits signal group is a collection of flags described in the "SIM101 signal groups" section of this document and as with any isolation state related message they should be checked to validate the estimates, the condition of the SIM101 and the presence of any warnings or alerts.

The ≈isolation_capacitances signal group provides the following information:

Signal	*Byte#*	*Units*	*Description*
Cp	2-3	nF	Estimate for the total capacitance between the positive power rail and chassis.
Cp_uncertainty	4	%	Uncertainty of Cp estimate
Cn	5-6	nF	Estimate for the total capacitance between the negative power rail and chassis.
Cn_uncertainty	7	%	Uncertainty of Cn estimate

Voltages Vp and Vn

The "Request voltages Vp and Vn" message and the SIM101 response is intended to provide individual measurements for the voltages between the positive and negative power rails and the chassis. Vp and Vn values are updated and can be sampled every 10 ms. If they are sampled at a lower frequency the voltage values will represent the average value between successive reads. The sampled values of Vp and Vn include the effect of the excitation voltage pulse of SIM101. The sum of Vp-Vn provides the battery voltage Vb. The "Request voltages Vp and Vn" format is as follows:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE3	

On "Request voltages Vp and Vn" the SIM101 will respond with a message composed of two "signal groups", the **≈Status_bits** and **≈voltages_Vp_and_Vn**.

SIM101 response:

Ext. ID	OpCode_mux	byte 1	bytes 2-7
0xA100100	0xE3	≈Status_bits	≈voltages_Vp_and_Vn

The **≈Status_bits** signal group is a collection of flags described in the "SIM101 signal groups" section of this document and as with any isolation state related message they should be checked to validate the estimates, the condition of the SIM101 and the presence of any warnings or alerts.

The **≈voltages_Vp_and_Vn** signal group provides the following information:

Signal	*Byte#*	*Units*	*Description*
Vp	2-3	V	Measured voltage between the positive power rail and chassis
Vp_uncertainty	4	%	Uncertainty of Vp measurement
Vn	5-6	V	Measured voltage between the negative power rail and chassis
Vn_uncertainty	7	%	Uncertainty of Vn measurement

Battery voltage

The "Request battery voltage" message and the SIM101 response is intended to provide a measurement for the battery voltage and its maximum value. The battery voltage value Vb is updated every 10 ms and the reported value corresponds to the average since the last request. The maximum battery voltage value Vb_max is the maximum value between the Max_battery_working_voltage value and the maximum actual Vb value recorded by SIM101 since power-on or reset. Default value of Max_battery_working_voltage is zero. If the Max_battery_working_voltage is not set by the host via the maintenance mode then Vb_max will be tracking the maximum value measured by SIM101. The Vb_max value is utilized by SIM101 to determine a warning or fault condition and set the appropriate flags in **≈Status_bits.** When evaluating warning or fault condition, the Vb_max value will be taken equal to the SIM101 module voltage rating if Max_battery_working_voltage is set to its default value (0V) and the SIM101 has not recorded any non-zero voltages for Vb

The "Request voltages Vp and Vn" format is as follows:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE4	

On "Request voltages Vp and Vn" the SIM101 will respond with a message composed of two "signal groups", the ≈Status_bits and ≈battery_voltage.

SIM101 response:

Ext. ID	OpCode_mux	byte 1	bytes 2-7
0xA100100	0xE4	≈Status_bits	≈battery_voltage

The **≈Status_bits** signal group is a collection of flags described in the "SIM101 signal groups" section of this document and as with any isolation state related message they should be checked to validate the estimates, the condition of the SIM101 and the presence of any warnings or alerts.

The **≈battery_voltage** signal group provides the following information:

Signal	*Byte#*	*Units*	*Description*
Vb	2-3	V	Measured DC power supply voltage
Vb_uncertainty	4	%	Uncertainty of Vb measurement
Vb_max	5-6	V	Maximum between Max_battery_working_voltage and measured Vb voltage since power-on or reset.
Vb_max_uncertainty	7	%	Uncertainty of Vb_max if it represents measured value

Error flags

The "Request error flags" message and the SIM101 response is intended to provide diagnostic information derived during the self-test of SIM101. This message should be invoked by the host anytime the Hardware_Error flag in the **≈Status_bits** signal group is set. The "Request error flags" format is as follows:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE5	

On "Request error flags" the SIM101 will respond with a message composed of two "signal groups", the ≈Status_bits and ≈Error_flags.

SIM101 response:

Ext. ID	OpCode_mux	byte 1	byte 2 - 3
0xA100100	0xE5	≈Status_bits	≈Error_flags

Dynamic capacitance energy state

The "Request dynamic capacitance energy state" message and the SIM101 response is intended to provide dynamic estimates of the potentially hazardous energy, stored in the IT system Y and parasitic capacitors. The energy stored is calculated as $E = 0.5\ V^2 C_t$, where V is the max(Vp, Vn) and Ct is the sum of all capacitances between power rails and chassis. The response of SIM101 includes the estimate of the total system capacitance. The "Request dynamic capacitance energy state" format is as follows:

Request from host:

Ext. ID	Request_mux	byte 1-2

0xA100101	0xE6

On "Request dynamic capacitance energy state" the SIM101 will respond with a message composed of two "signal groups", the ≈Status_bits and ≈Error_flags.

SIM101 response:

Ext. ID	OpCode_mux	byte 1	byte 2 - 7
0xA100100	0xE6	≈Status_bits	≈safety_touch_energy

Dynamic isolation state

The "Request dynamic isolation state" message and the SIM101 response is intended to provide dynamic estimates of the potentially hazardous touch current, as determined by the actual battery/power supply operating voltage and the min(Rp, Rn). The touch current estimate is provided in Ω/V. Along with the touch current estimate SIM101 returns also the actual operating battery/power supply voltage. The "Request dynamic isolation state" format is as follows:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE7	

On "Request dynamic capacitance energy state" the SIM101 will respond with a message composed of two "signal groups", the ≈Status_bits and ≈Error_flags.

SIM101 response:

Ext. ID	OpCode_mux	byte 1	byte 2 - 7
0xA100100	0xE7	≈Status_bits	≈Safety_touch_current

Request Vn high resolution

The SIM101 monitors the voltage between the negative power rail of the IT system and chassis and can report the value with 32-bit accuracy. The value reported is the average value since the last request and it is updated every 10 ms. The reported value includes the effects of the excitation signal. The Vn_hi_res 32-bit signed integer (µV units) signal byte order is Motorola (Big endian).

To read Vn_hi_res the host sends:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x60	

SIM101 response:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x60	Vn_hi_res

Request Vp high resolution

The SIM101 monitors the voltage between the positive power rail of the IT system and chassis and can report the value with 32-bit accuracy. The value reported is the average value since the last request and it is updated every 10 ms. The reported value includes the effects of the excitation signal. The Vp_hi_res 32-bit signed integer (µV units) signal byte order is Motorola (Big endian).

To read Vp_hi_res the host sends:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x61	

SIM101 response:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x61	Vp_hi_res

Request Vexc high resolution

The SIM101 monitors the voltage between the excitation pulse applied to both power rails of the IT system and chassis and can report the value with 32-bit accuracy. The value reported is updated every 10 ms and corresponds to the average since the last request. The reported value includes the effects of the excitation signal. The Vexc_hi_res 32-bit signed integer (µV units) signal byte order is Motorola (Big endian).

To read Vexc_hi_res the host sends:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x62	

SIM101 response:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x62	Vexc_hi_res

Request Vb high resolution

The SIM101 monitors the voltage between the positive power and negative rail of the IT system and can report the value with 32-bit accuracy. The value reported is updated every 10 ms and corresponds to the average since the last request. The Vb_hi_res 32-bit signed integer (µV units). Signal byte order is Motorola (Big endian).

To read Vb_hi_res the host sends:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x63	

SIM101 response:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x61	Vp_hi_res

Request Vpwr high resolution

The SIM101 monitors the voltage of its own power supply with 32-bit accuracy. The value reported is updated every 10 ms and corresponds to the average since the last request. The reported value includes the effects of the excitation signal. The information can be used for diagnostic purposes. The Vp_hi_res 32-bit unsigned integer (µV units) signal byte order is Motorola (Big endian).

To read Vpwr_hi_res the host sends:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x65	

SIM101 response:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x65	Vpwr_hi_res

Request Uptime counter

The SIM101 monitors the time since its last reset. The value reported is in seconds. The reported value can be used for debugging purposes. The Uptime_counter 32-bit unsigned integer (µV units) signal byte order is Motorola (Big endian).

To read Uptime_counter the host sends:

Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0x0C	

SIM101 response:

Ext. ID	OpCode_mux	byte 1-4
0xA100100	0x0C	Uptime_counter

SIM101 state control commands from Host

Restart

The "Restart" command forces the SIM101 to enter a power-on state. Specifically:

- Clears all flags in ≈Status_bits signal group
- Clears all flags in ≈Error_flags signal group
- Clears all isolation state estimates

- Clears the contents of Uptime counter
- Reloads from flash memory Max_battery_working_voltage into Vb_max

After a "Restart" command the SIM101 will perform self-check and will produce new estimates and update flags within 5 s.

The "Restart" command is as follows:

Ext. ID	Request_mux	Byte 1	Byte 2
0xA100101	0xC1	0x01	0x23

Turn excitation pulse off

The "Turn excitation pulse off" disables the excitation pulse of SIM101 and suspends its isolation monitoring function. The purpose of this command is to prevent SIM101 from interfering with another insulation monitoring device which is currently active. For example, if the SIM101 operates in a vehicle the "Turn excitation pulse off" command shall be used when and while the vehicle is attached to a DC quick charging station. When this command is executed the "Excitation Off" flag in status register will be set and IS1 IS0 flags will be set to 0 and 1 respectively to indicate an undetermined isolation state. While the excitation pulse is turned off measurements will not be valid and the relevant error flags will be set. The SIM101 shall resume its isolation monitoring function through the issuance of a "Restart" command.

The "Turn excitation pulse off" command is as follows:

Ext. ID	Request_mux	Byte 1	Byte 2
0xA100101	0xC1	0xEC	0x00

Lock excitation signal high

The "Lock excitation signal high" sets the excitation signal at its high value of +12.5 V. It can be used for diagnostic purposes. While the excitation pulse is set high measurements will not be valid and the relevant error flags will be set. The SIM101 shall resume its isolation monitoring function through the issuance of a "Restart" command.

The "Lock excitation signal high" command is as follows:

Ext. ID	Request_mux	Byte 1	Byte 2
0xA100101	0xC1	0xEC	0x01

Lock excitation signal low

The "Lock excitation signal high" sets the excitation signal at its low value of -12.5 V. It can be used for diagnostic purposes. While the excitation pulse is set high measurements will not be valid and the relevant error flags will be set. The SIM101 shall resume its isolation monitoring function through the issuance of a "Restart" command.

The "Lock excitation signal low" command is as follows:

Ext. ID	Request_mux	Byte 1	Byte 2
0xA100101	0xC1	0xEC	0x02

Differences with SIM100

New signals in SIM101

SIM101 introduces new signals and messages that are highlighted on each relevant section of this document. Specifically, SIM101 introduces the following new signals:

SIM101 new signals

Signal Name	*Length [Bits]*	*Byte Order*	*Value Type*	*Unit*	*Value Table*	*Comment*
Err_Clock	1	-	B			0 – No timing errors 1 – SIM101 clock error
Err_Watchdog	1	-	B			0 – No watchdog error 1 – Watchdog error
Err_Temp	1	-	B			0 – Temperature normal 1 – Temperature higher than 105 C
Exc_off	1	-	B			0 – Excitation pulse operating 1 – Excitation pulse is turned off
FW_version	64	M	U		-	Firmware version encoded as: Byte 0-1: Major version Byte 2-3: Minor version Byte 4-5: Patch Byte 6-7: Pre version
Touch_energy	16	M	U	mJ		Dynamic calculation of capacitive discharge potential energy, based on the actual max(Vp, Vn) rail to chassis voltage and total capacitance. Updated each 4.5 s.
Touch_energy_uncertainty	8	M	U	%		Discharge energy uncertainty expressed in %
Touch_isolation	16	M	U	Ω/V		Minimum resistance/Volt path, between IT system & chassis. The value is calculated upon the actual operating Vb. Updated each 10 ms.
Touch_isolation_uncertainty	8	M	U	%		Uncertainty on estimation of Touch_isolation

Signal Name	*Length [Bits]*	*Byte Order*	*Value Type*	*Unit*	*Value Table*	*Comment*
`Touch_energy_fault`	1		B			0 – Capacitive energy stored within limit 1 – Capacitive energy stored exceeds 0.2 J limit
`Uptime_counter`	32	M	U	s	-	Time since reset in seconds
`Vb_hi_res`	32	M	S	µV	-	Reports voltage of monitored IT power system in µV. Updated every 10 ms.
`Vexc_hi_res`	32	M	S	µV	-	Returns the value of the excitation signal in µV. Updated every 10 ms.
`Vpwr_hi_res`	32	M	U	µV	-	Value of SIM101 power supply in µV. Updated every 10 ms.

DLC in SIM100 and SIM101

All messages originating from the host in SIM101 can have a constant DLC = 3. Message bytes not defined in this document will be ignored by SIM101. For backwards compatibility purposes the SIM101 V2.0 and higher will keep recognizing messages defined as DLC=1 in previous versions.

New messages in SIM101

New messages from the host defined in this version are the following:

`SIM101_Request_mux new values in V2.0`

Value	*Name*	*Data bytes*	*Description*
0x0C	Request Uptime counter	2	Request signal `Uptime_counter`
0x62	Request Vexc high resolution	2	Request signal `Vexc_hi_res`
0x63	Request Vb high resolution	2	Request signal `Vb_hi_res`
0x65	Request Vpwr high resolution	2	Request signal `Vpwr_hi_res`
0xC1	Command to SIM101	2	Action determined by the values of data bytes: *byte1* / *byte2* / *Action* 0x01 / 0x23 / Reset 0xEC / 0x00 / Disable excitation signal 0xEC / 0x01 / Lock excitation signal high 0xEC / 0x02 / Lock excitation signal low
0xE6	Request dynamic capacitance energy state	2	Request signal group ≈`safety_touch_energy`
0xE7	Request dynamic isolation state	2	Request signal group ≈`Safety_touch_current`

Messages eliminated in this version

"Set Max battery working voltage command has been eliminated in this version.

Request from Host:

Ext. ID	Request_mux	Bytes 1-2
0xA100101	0xF0	Max_battery_working_voltage

Max battery working voltage can now be set only in "Maintenance mode".

Additional files

"SIM101 Firmware v2 - Maintenance Mode" v1.0

CAN_Protocol_SIM101_v2.3.dbc

Sample SIM101 transaction

Read isolation state

In this example the host requests the isolation state of the IT system. The SIM101 responds with new data indicating minimum electrical isolation of 550 Ω/V with uncertainty of 2% and maximum energy stored in capacitors under maximum working voltage of 80 mJ with uncertainty of 4%.

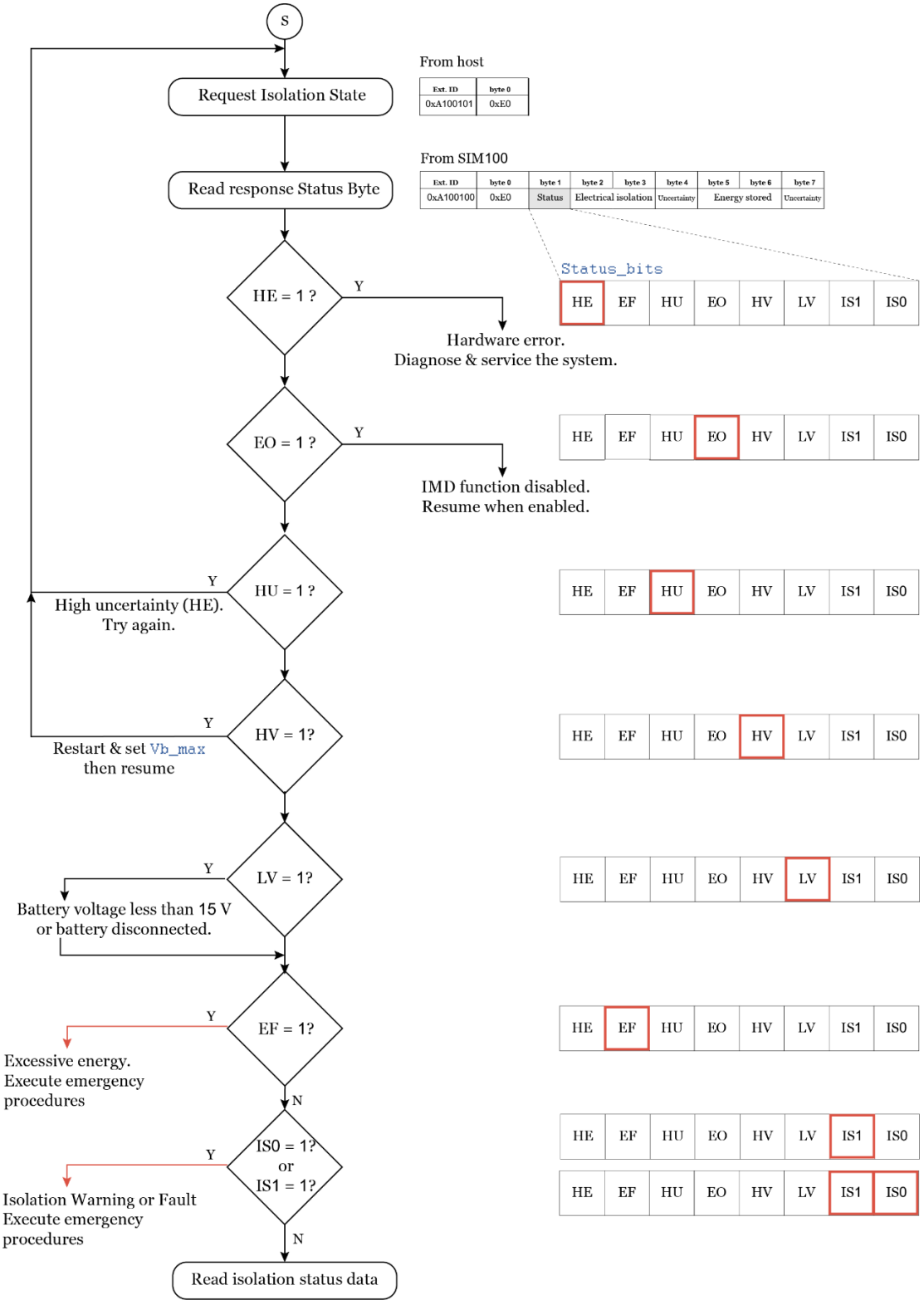
Request from host:

Ext. ID	Request_mux	byte 1-2
0xA100101	0xE0	

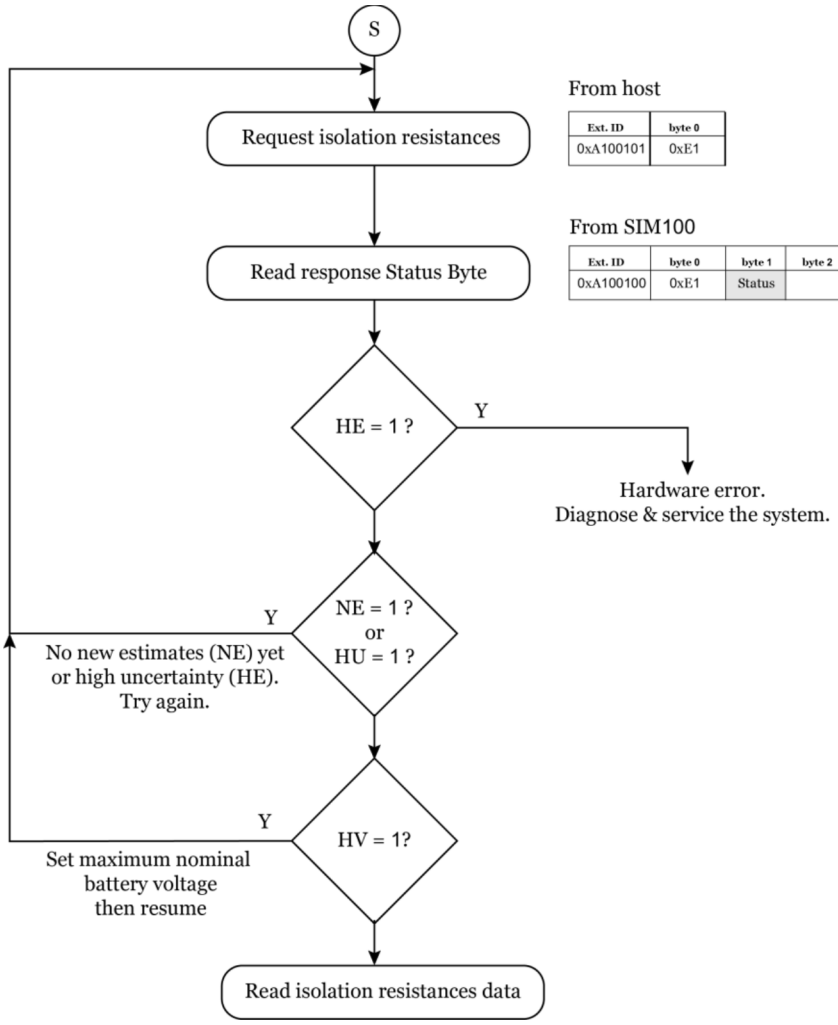
Response from SIM101:

Ext. ID	OpCode_mux	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7
0xA100100	0xE0	0x00	0x02	0x26	0x02	0x00	0x50	0x04

Read Status_bits typical flowchart



"Request isolation resistances" typical flowchart



From host

Ext. ID	byte 0
0xA100101	0xE1

From SIM100

Ext. ID	byte 0	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7
0xA100100	0xE1	Status	Rp		Uncertainty	Rn		Uncertainty

Revision history

V2.3	8/2021	Vb_hi_res signal defined as signed integer
V2.2	5/2021	Introduce "Request dynamic capacitance energy state" and "Request dynamic isolation state" messages
V2.1	4/2021	Introduce "touch energy" and "touch current" signals.
V2.0	3/2021	Initial release of V2.0. Introduces new signals & messages. Backwards compatible with v0.8a implementations except "Set Max Voltage" message which is now supported only in Maintenance mode. Maintenance mode documented in separate document.