

Skywire 4G LTE Cat 4 and Cat 1 NA Embedded Cellular Modem Datasheet

NimbeLink Corp

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1. Introduction

1.1 Scope

This document serves as the hardware datasheet for the NL-SW-LTE-TC4NAG and the NL-SW-LTE-TC1NAG Skywire® modems. This document is updated often, please be sure to download the latest version from NimbeLink's website.

1.2 Contact Information

NimbeLink's goal is to make integrating Skywire modems into end-user applications as easy as possible. Please send any feedback, documentation requests, or technical support questions to NimbeLink's product support team at:

product.support@nimbelink.com

For purchasing information, please visit the "Part Ordering Information" section on the modem's product page. Any additional sales questions or requests for quotation can be directed to NimbeLink's sales team at:

sales@nimbelink.com

1.3 Orderable Part Numbers

Orderable Device	Operating Temperature	4G LTE Bands	Fallback
NL-SW-LTE-TC4NAG NL-SW-LTE-TC1NAG	-40 °C to +85 °C	LTE-FDD: B2, B4, B5, B12, B13, B14, B66, B71	3G HSPA+: B2, B4, B5

1.4 Additional Resources

- [Skywire® 4G LTE CAT 4 NA Embedded Modem Product Page](#)
- [Skywire® 4G LTE CAT 1 NA Embedded Modem Product Page](#)
- [Skywire® TCxNAG AT Command Manual](#)
- [Skywire® TCxNAG Application Notes](#)
- [Skywire® TCxNAG 3D Model \(STEP\)](#)
- [NL-SWDK User Manual](#)
- [Skywire Hardware Design Developers Guide](#)
- [Skywire Hardware Design Checklist](#)
- [Skywire Software Developers Guide](#)

1.5 Product Overview

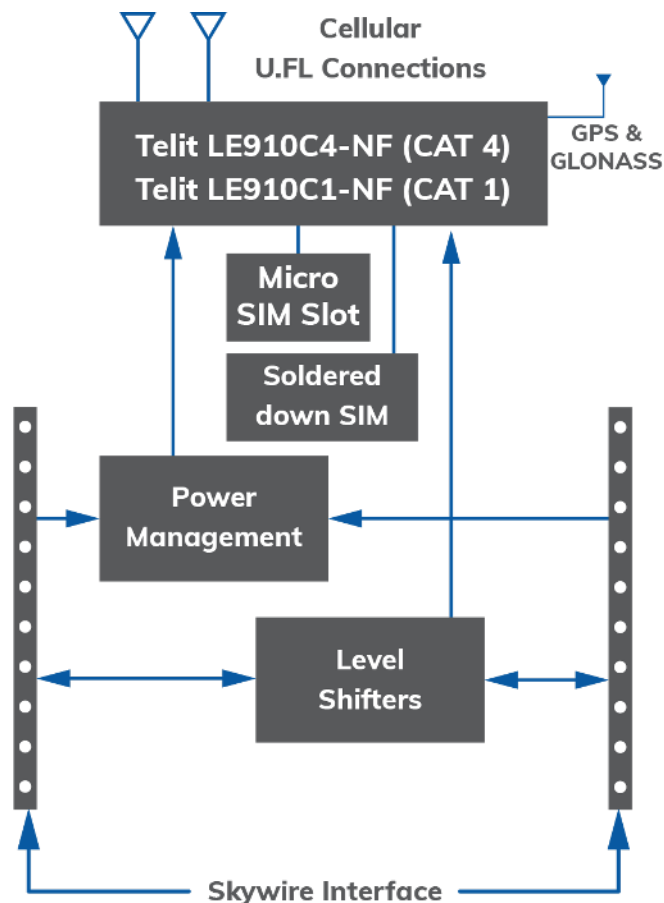
NimbeLink, a global leader in embedded cellular modem technology and asset tracking solutions, has introduced the Skywire® 4G LTE CAT 4 NA and Skywire® 4G LTE CAT 1 NA modems. These Skywire modems leverage Category 4 and Category 1 technology, respectively. The NL-SW-LTE-TCxNAG family is ideal for delivering fast reliable cellular connectivity to products with applications in North America.

The modems support GNSS, dual SIMs, a single SKU for both AT&T and Verizon networks, integrated TCP/IP stacks, and is AT&T's FirstNet (Band 14) capable.

The NL-SW-LTE-TCxNAG family is pin-compatible with all other Skywire form factor modems. This offers the flexibility of being able to use multiple vendors in one hardware design of your end product.

2. Technical Specifications

2.1 Block Diagram



2.2 Electrical Specifications

2.2.1 Absolute Maximum and Minimum Ratings

To avoid potential damage to the modem, ensure that all voltages applied to the pins listed below do not fall outside of the ranges specified by the maximum and minimum ratings:

Parameter	Skywire Pin(s)	Min. Rating	Max. Rating
Main Power Supply ¹	VCC	3.4V	4.2V
Main Power Supply Ripple Voltage	VCC		30mV
I/O Voltage Reference	VREF	1.8V	5.5V
1.8V Referenced Signals	GPIO1, GPIO2, ON_OFF, nRESET	0 V	1.8V
VREF Referenced Signals	DIN, DOUT, DTR, RING, CTS, RTS	0 V	5.5V

1. Transient voltage drooping can occur on the VCC rail during normal modem operation. In order to prevent damage to the modem, transient voltage drops must not fall below 3.1V.

2.2.2 Module Pinout for Connectors J1 and J2

The following table details the pinout of the NL-SW-LTE-TCxNAG Skywire modems, and recommended ratings for the Skywire interface on connectors J1 and J2. More details and design requirements for these pins are documented in [Section 3](#).

Pin	Name	Direction	Description	Min	Typ.	Max
1 (J1-1)	VCC	Input	Main Power Supply Pin	3.4V	3.8V	4.2V
2 (J1-2)	DOUT	Output	UART data out, I/O level tied to VREF, internally pulled up to VREF.	0V		VREF
3 (J1-3)	DIN	Input	UART data in, I/O level tied to VREF	VREF Range	VIL	VIH
				1.65V to 1.95V	VREF x 0.35V	VREF x 0.65
				2.3V to 2.7V	0.7V	1.7V
				3.0V to 3.6V	0.8V	2V
				4.5V to 5.5V	VREF x 0.3V	VREF x 0.7
4 (J1-4)	GND	Input	Ground Pin		0V	

Pin	Name	Direction	Description	Min	Typ.	Max
5 (J1-5)	nRESET	Input	Reset signal for the LE910Cx cellular module, active low, drive with an open collector transistor. See Section 3.4 for additional requirements.	VIL	0V	0.6V
				VIH	1.25V	1.8V
6 (J1-6)	VUSB	Input	USB connection detection	2.5V	5.0V	5.5V
7 (J1-7)	USB_P	I/O	USB differential data bus (+) Requires differential impedance of 90Ω.	Compliant with USB 2.0 standard specification.		
8 (J1-8)	USB_N	I/O	USB differential data bus (-) Requires differential impedance of 90Ω.	Compliant with USB 2.0 standard specification.		
9 (J1-9)	DTR	Input	Data terminal ready (sleep mode control), tied to internal reference voltage of 1.8V	VIL	0V	0.63V
				VIH	1.17V	5.5V
10 (J1-10)	GND	Input	Ground Pin		0V	
11 (J2-1)	GND	Input	Ground Pin		0V	
12 (J2-2)	CTS	Output	Modem "Clear to Send" hardware flow control output, open drain assertion, internally pulled up to VREF.	VREF Range	VIL	VIH
				1.65V to 1.95V	VREF x 0.35V	VREF x 0.65
				2.3V to 2.7V	0.7V	1.7V
				3.0V to 3.6V	0.8V	2V
				4.5V to 5.5V	VREF x 0.3V	VREF x 0.7
13 (J2-3)	ON/nSLEEP	Output	Modem status pin. See Section 3.6 for further information.	0V		1.8V
14 (J2-4)	VREF	Input	Voltage reference for offboard I/O signals.	1.65V	1.8V or 3.3V	5.5V

Pin	Name	Direction	Description	Min	Typ.	Max
15 (J2-5)	GND	Input	Ground Pin		0V	
16 (J2-6)	RTS	Input	Modem "Request to Send" hardware flow control input	VREF Range	VIL	VIH
				1.65V to 1.95V	VREF x 0.35V	VREF x 0.65
				2.3V to 2.7V	0.7V	1.7V
				3.0V to 3.6V	0.8V	2V
				4.5V to 5.5V	VREF x 0.3V	VREF x 0.7
17 (J2-7)	GPIO_3	I/O	Modem GPIO pin. 2-16 mA drive strength.	VIL	0V	0.6V
				VIH	1.25V	1.8V
				VOL	0V	0.45V
				VOH	1.4V	1.8V
18 (J2-8)	GPIO_2	I/O	Modem GPIO pin. 2-16 mA drive strength.	VIL	0V	0.6V
				VIH	1.25V	1.8V
				VOL	0V	0.45V
				VOH	1.4V	1.8V
19 (J2-9)	RING	Output	Modem Ring indicator pin. Open drain output, pulled up to VREF on Skywire. Pulled low when a new modem URC is available.	0V		VREF
20 (J2-10)	ON_OFF	Input	Modem On/Off signal, active low, drive with an open collector transistor. See Section 3.5 for additional requirements.	VIL	0V	0.2V
				VOH	0.7V	0.9V

Additional information on the Skywires pinout is available in Section 3.

2.2.3 Module Pinout for Connectors X1, X2, X3, J3

Connector Designator	Description	Connector Location
X1	Primary Cellular Antenna Connector	Top Side of Modem
X2	Diversity Cellular Antenna Connector	Top Side of Modem
X3	GPS / GNSS Antenna Connector	Bottom Side of Modem
J3	Micro SIM Connector	Bottom Side of Modem

2.2.4 Typical Power Consumption

The values contained in Section 2.2.4 are provided as an example of typical current consumption behavior for NL-SW-LTE-TCxNAG Skywires.

In customer applications, current consumption may vary, and is influenced by factors such as: signal quality, ambient temperature, battery/supply voltage, supply impedance, board capacity, and other factors.

TC4NAG							
Mode	Signal Attn. (dB)	RSSI (dBm)	LTE: RSRQ (dB) 3G: EC/IO (dB)	Peak Current (mA)	Average Current (mA)	Charge Consumed (mAh)	Measurement Notes
Active Socket Dial, 4G LTE	0	-51	-8	916.8 mA	83.5 mA	43.4 μAh	Tested at: 3.8V Time elapsed: 1.73 s Test: Open socket, HTTP POST, read response, close socket
	20	-71	-10	844.6 mA	113.8 mA	64.0 μAh	Tested at: 3.8V Time elapsed: 1.95 s Test: Open socket, HTTP POST, read response, close socket
	40	-89	-12	958.7 mA	136.7 mA	110.2 μAh	Tested at: 3.8V Time elapsed: 2.76 s Test: Open socket, HTTP POST, read response, close socket
Active Socket Dial, 3G HSPA+	0	-83	-5	449.4 mA	236.1 mA	127.7 μAh	Tested at: 3.8V Time elapsed: 1.95 s Test: Open socket, HTTP POST, read response, close socket
	20	-97	-8	594.2 mA	354.9 mA	236.5 μAh	Tested at: 3.8V Time elapsed: 2.40 s Test: Open socket, HTTP POST, read response, close socket
	40	-203	-11	576.9 mA	355.4 mA	301.7 μAh	Tested at: 3.8V Time elapsed: 3.05 s Test: Open socket, HTTP POST, read response, close socket

TC4NAG							
Mode	Signal Attn. (dB)	RSSI (dBm)	LTE: RSRQ (dB) 3G: EC/IO (dB)	Peak Current (mA)	Average Current (mA)	Charge Consumed (mAh)	Measurement Notes
GPS Location Fix, Cold Start	0	-51	-8	805.9 mA	76.1 mA	413.2 μ Ah	Tested at: 3.8V Time elapsed: 37.8 s Test: GPS cold start, active GPS antenna, registered on LTE network, time-to-fix measurement
GPS Location Fix, Hot Start	0	-51	-8	166.4 mA	64.6 mA	8.5 μ Ah	Tested at: 3.8V Time elapsed: 29 s Test: GPS hot start, active GPS antenna, registered on LTE network, time-to-fix measurement
Idle, Registered on LTE network	0	-51	-8	837.6 mA	19.1 mA	1.6 mAh	Tested at: 3.8V Time elapsed: 300 s Test: 5 minute idle while modem is registered on network. Status LED enabled.
Idle, Unregistered on LTE network	0	-51	-8	104.5 mA	14.8 mA	1.2 mAh	Tested at: 3.8V Time elapsed: 300 s Test: 5 minute idle with AT+CFUN=4, and modem unregistered. Status LED enabled.
Off	0	-51	-8	525.4 μ A	4.4 μ A	365.0 nAh	Tested at: 3.8V Time elapsed: 300 s Test: Modem powered off with AT#SHDN.

Note: TC1NAG Power Consumption Data Coming Soon

2.3 RF Specifications

2.3.1 Maximum RF Output Power

Available Cellular Technologies and Max TX Power		
	TC4NAG	TC1NAG
4G LTE Technology	4G LTE CAT 4	4G LTE CAT 1
4G LTE TX Output Power	23 ± 0.5 dBm	
3G Technology	HSPA+	
3G TX Output Power	23.5 ± 0.5 dBm	

2.3.2 RX Sensitivity

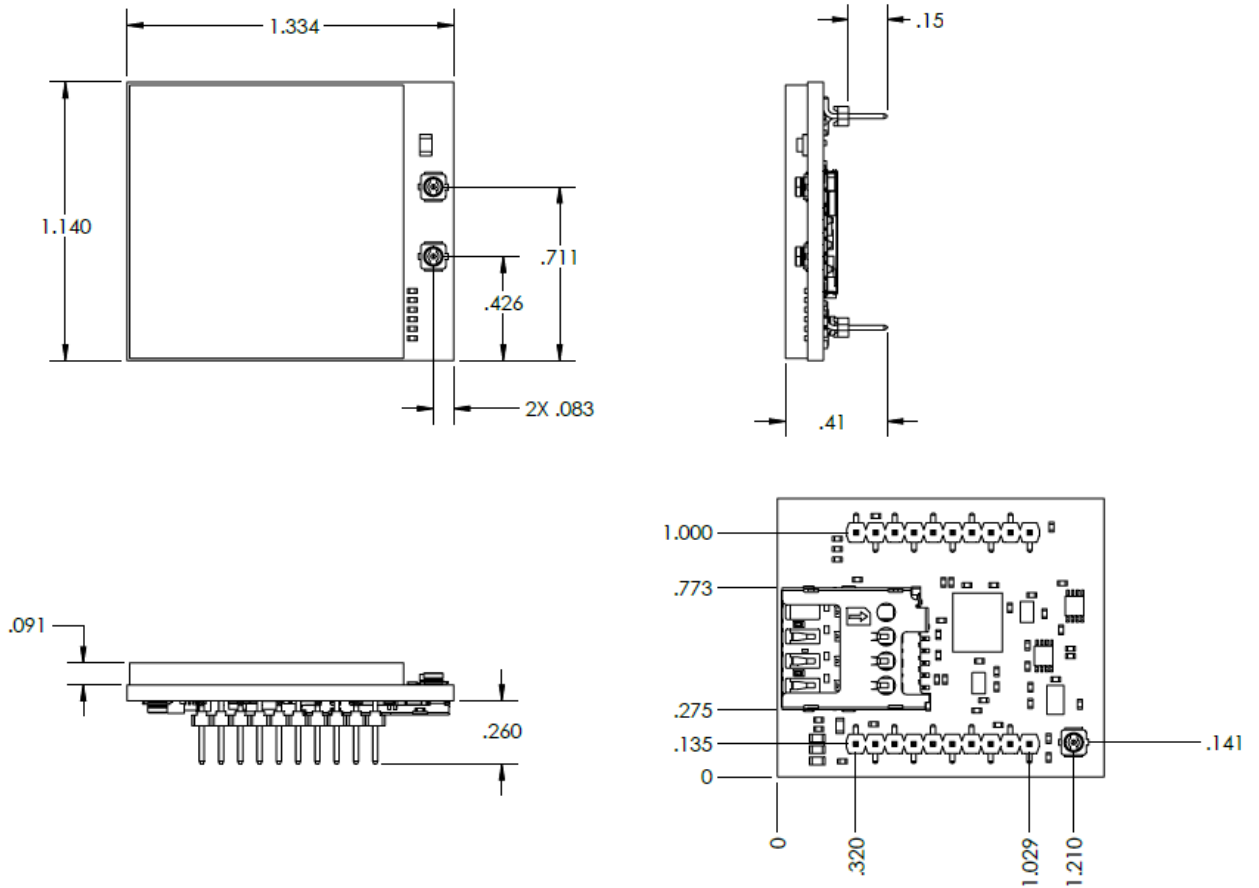
Available Cellular Technologies and RX Sensitivity	
4G	-102.0 dBm (@ 5 MHz BW)
3G	-112.0 dBm (@ 5 MHz BW)

2.3.3 4G LTE Uplink and Downlink Speeds

4G LTE Peak Uplink and Downlink Speeds		
	TC4NAG	TC1NAG
Uplink	50 Mbps	5 Mbps
Downlink	150 Mbps	10 Mbps

2.4 Mechanical Characteristics

2.4.1 Mechanical Drawing



Dimensions are in inches unless noted.

2.4.2 Mechanical Specifications

Parameter	Typical	Unit
Dimensions	29.0 x 33.9 x 10.7	mm
	1.140 x 1.334 x 0.41	Inches
Weight	8	Grams
Connector Insertion/Removal	hundreds	Cycles

2.4.3 Mating Connectors

Connector Designator	Manufacturer	Populated on Skywire	Recommended Mate	Mate Manufacturer
J1, J2	3M	951110-2530-AR-PR	950510-6102-AR	3M
			NPPN101BFCN-RC	Sullins Connector Solutions
J3	Molex	786463001	Micro SIM 3FF Size	Micro SIM Card
X1, X2	Hirose	U.FL-R-SMT(10)	CAB.011	Taoglas

2.4.4 Device Placement

⚠ Make sure the Skywire is installed in the correct orientation in your host board. Failure to do so will damage the device and void the warranty.

2.4.5 Environmental Specifications

Parameter	Min	Typical	Max	Unit	Note
Operating Temperature	-40	+25	+85	°C	
Storage Temperature	-40	+25	+85	°C	
Operating Humidity	20		90	%	Non-condensing

3. Design Considerations

Section 3 describes important considerations that system designers should follow when utilizing a Skywire modem in a new or existing design.

NimbeLink offers free schematic and layout design reviews for customers integrating Skywire modems into their designs. Contact the following email for information:

product.support@nimbelink.com.

To aid with customer design efforts NimbeLink has released a Skywire Hardware Developers Guide and a Design Checklist. These supplemental documents contain design guidelines and suggestions for customers designing Skywire modems into their hardware platforms. NimbeLink strongly suggests reviewing your hardware platform against these documents to ensure proper modem integration.

- [Skywire Hardware Developers Guide](#)
- [Skywire Hardware Design Checklist](#)

3.1 Power Supply Design

[Section 3.1](#) contains information regarding proper power supply design for users who are designing their own baseboard for a Skywire modem. In order to ensure proper modem operation and prevent potential damage, it is crucial to follow each of the requirements listed in this section.

3.1.1 Power Supply Requirements

NL-SW-LTE-TCxNAG Skywires have a normal operating voltage range of 3.40V to 4.20V, with a recommended input voltage of 3.80V. These modems will regularly consume high amounts of current on its main power supply inputs (Pin 1, VCC) and must have a well designed power supply that can support peak transient currents up to 2 Amps.

Parameter	Symbol	Min	Typ	Max	Unit
Operating Voltage Range	VCC	3.40	3.8	4.20	V
Current Consumption*	I _{VCC}	-	400	2000	mA

*Current consumption values depend on network configuration and are not under the modem's control.

Designers must ensure that the supply voltage does not drop outside of the normal operating range at all times during modem operation. Failure to do so may cause the modem to brownout, which can cause permanent damage to the modem and void the modem's warranty.

When designing the power supply for a Skywire modem it is recommended to adhere to the following design guidelines:

- Use a DC-DC switching power supply that is capable of supplying up to 2A of current to the Skywire.
 - Switching power supplies are able to rapidly respond to the sudden current demands of an LTE modem.
 - It is recommended to use a regulator with an output voltage of 3.8V.
 - To reduce EMI from the switching regulator, follow the manufacturer design guidelines closely.
- Place a minimum of a 0.1 μ F low ESR ceramic capacitor and 100 μ F low ESR ceramic capacitor close to the VCC pin of the Skywire.
 - The 0.1 μ F capacitor should be placed as close as possible to the VCC pin of the Skywire followed by the 100 μ F capacitor.
 - The capacitors should be rated to at least twice the output voltage of the switching regulator.
 - See the reference schematics below for example power supply circuits.
- Ensure that there is a low impedance power path from the baseboard power supply to the VCC pin of the Skywire.
 - Use at least an 80 mil trace width for the power supply trace to the VCC pin. However, the wider the trace, the better.
 - An increased trace width will lower the inductance of the trace, improving the ability of the power supply to meet the transient current spikes of up to 2A during cellular network activity.
- Use a dedicated ground plane on the baseboard.
- Power supply input cables should be kept away from noise sensitive signal lines, such as antennas or USB traces.

NimbeLink offers multiple reference designs in order to assist customers with their designs at no charge. Two of the designs are linked to below:

NL-AB-BBCL Reference Schematic:

https://nimbelink.com/Documentation/Development_Kits/NL-AB-BBCL/20057s_NL-AB-BBCL_SCH.PDF

NL-SWDK Reference Schematic:

https://nimbelink.com/Documentation/Development_Kits/NL-SWDK/20002_NL-SWDK_Schematic.pdf

While prototyping with the modem, it is recommended to use a Skywire development kit, as opposed to a breadboard. Please refer to the following application note on why breadboards might cause problems and how to fix them:

Prototyping with Cellular Modems and Modules:

https://nimbelink.com/Documentation/Skywire/1001619_Breadboard_WhitePaper.pdf

3.2 Serial Communications

The NL-SW-LTE-TCxNAG modems have two communication paths: serial (UART) and USB. The serial UART interface is targeted for applications using lower speed 8/16/32 bit microcontrollers that do not have a USB interface or easily-available USB interface drivers.

The USB interface for the modem is meant to be used by higher-end systems with a native USB interface controller or operating system, like single-board computers running Linux or Windows.

For designs that are only using the serial UART interface, NimbeLink recommends including test points or a non-populated USB connector footprint in the design. This allows optional access to the modem's USB interface, which enables easy debugging and firmware updates.

3.2.1 Serial UART Interface

All Skywire modems support a serial UART interface with transmit and receive on pins 2 (DOUT) and 3 (DIN), respectively.

On NL-SW-LTE-TCxNAG modems, the baud rate defaults to 115200 Baud 8N1. If a different baud rate is required, it can be changed with the "AT+IPR" command, as defined in the AT command manual. The syntax of the "AT+IPR" command is as follows:

AT+IPR=<rate>

Where "<rate>" is any supported baud rate listed in the AT command manual.

The modems also support hardware flow control (RTS/CTS) on pins 12 (CTS) and 16 (RTS). By default, the modems do have flow control enabled.

To modify the flow control setting, see the "AT&K" command from the AT command manual. The syntax of the "AT&K" command is as follows:

AT&K<x>

Where "<x>" is replaced either "0" to disable flow control, or "3" to enable flow control.

It is recommended that any designs using the serial UART interface connect the RTS/CTS flow control lines to the host microcontroller and enable them in their application.

3.2.2 USB Interface

The NL-SW-LTE-TCxNAG Skywire modems support a USB 2.0 interface on pins 6 (VUSB), 7 (USB_P), and 8 (USB_N).

Systems connecting to the modem's USB interface must observe proper design practices for connecting to a high speed USB device including, but not limited to:

- The USB D± traces should be routed as a 90 ohm impedance differential pair.
- The USB D± traces should be length matched.
- USB trace lengths should be minimized.
- USB differential pairs should be carefully routed to ensure they have a continuous return path beneath the traces. Do not route differential pairs over splits in ground or power planes.
- If the USB signals will be used off-board, ESD protection should be implemented near the off-board connector.

Pin 6 (VUSB) is the pin that the modem uses to detect if a USB host controller has been connected to the modem. This pin has an internal pulldown and must have a voltage between 2.5V and 5.5V applied to it in order to activate the USB interface. The VUSB pin will draw less than 5mA when connected.

3.3 VREF

The VREF signal (pin J2-4) drives the input voltage side of an on-board buffer which converts external I/O voltage from the VREF range to the 1.8V range in order to drive the onboard cellular module.

System designers should connect the reference voltage of their system to this pin. The VREF signal will typically draw less than 5mA when the modem is powered, however this will depend on the host system's serial interface configuration.

If the baseboard powers down the modem at any time, it should also concurrently remove the reference voltage from the VREF pin.

3.4 nRESET

In the event that the modem becomes unresponsive, pin 5 (nRESET) can be grounded to unconditionally shut down the modem. When pin 5 is grounded, the modem will cease all ongoing operations and unconditionally shut down. The modem will need the ON_OFF signal applied again to power on after a nRESET condition.

Users can monitor the ON/nSLEEP pin to determine if the modem has powered down.

In most cases, network providers request that a device gracefully detach from the network before shutting down. Repeated use of the nRESET pin violates this request. As such, the nRESET pin should only be used as a last resort when the modem is not responding to AT commands.

Repeated failure to gracefully detach from the network during shutdown may result in the device being blacklisted from the network for a period of time, or indefinitely.

The nRESET signal is an active low signal. The signal is internally pulled up to the modem's internal 1.8V rail. Do not apply a voltage to this pin other than connecting it to ground.

To unconditionally shut down the modem with the nRESET signal, assert a logic-low level on nRESET using an open-drain or open-collector circuit for at least 200 ms, and then release.

If the signal is unused, it can be left floating, however, it is highly recommended that the signal be connected to the host system.

In high noise (high EMI) environments, NimbeLink recommends that designers place a 0.01 μ F - 0.1 μ F capacitor on the nRESET line near the J1 connector of the Skywire.

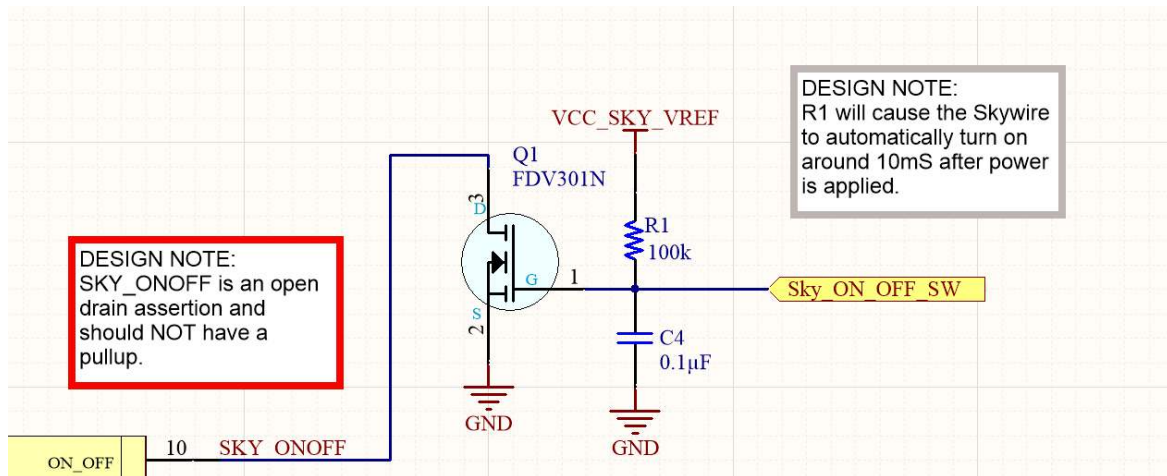
3.5 Power Control

3.5.1 ON_OFF Signal

The ON_OFF signal on pin 20 is used to trigger the modem to turn on and off. Do not power this pin nor apply a pullup resistor. Doing so may prevent the modem from booting, or may cause damage to the modem.

This signal is internally pulled up; user's will typically see around 800 mV on the signal's output. The maximum current draw for this pin is 0.1mA.

To conserve power, the on-board cellular module does not automatically boot when power is applied. Therefore, the baseboard design must supply a means to assert a logic-low level on the ON_OFF pin using an open-drain or open-collector circuit. An example circuit is shown in the image below.



To initiate the startup procedure, tie ON_OFF to ground for $1 < x < 2$ seconds. The modem will take approximately 20 seconds to turn on and be ready for AT commands.

To power down the modem, tie the ON_OFF pin to ground for at least 2.5 seconds.

Users can monitor the ON/nSLEEP pin to determine if the modem has powered down, this will typically take around 15 seconds for a controlled shutdown.

Tying the ON_OFF signal directly to ground to make the modem boot up when power is applied will cause the modem to automatically boot back up after a shutdown command is issued. This may prevent the modem from being able to shut down when the system is being powered off.

If the modem attempts to boot up while power is being removed it may suffer irreversible firmware corruption. Users are recommended to actively control this signal or use a one-shot circuit to apply the ON_OFF signal when power is applied.

3.5.2 Shutdown

The modem may be properly powered off using one of the following methods:

- Hardware shutdown using the ON_OFF signal.
- Shutdown using the "AT#SHDN" command.

Both of the shutdown options will force the modem to issue a detach request to the network, which informs the network that the device will be unreachable for an indefinite time. After issuing this request, the modem will power down.

For power sensitive applications it is also recommended to remove VCC and VREF from the Skywire after it has powered down. When the modem is powered down, the user must ensure that the modem is not being back-powered by any of its I/O lines.

Be sure to shut down the modem in a controlled manner, so as to allow the modem to gracefully detach from the network. Repeated failure to gracefully detach from the network during shutdown may result in the device being blacklisted from the network for a period of time, or indefinitely.

The duration of the shutdown process may vary from 15 seconds or longer. The host system should monitor the ON/nSLEEP pin to determine when the modem has powered down.

3.5.2.1 Hardware Shutdown

To shut down the modem using the hardware shutdown; tie the ON_OFF signal low for 2.5 seconds. Use the same open-drain or open-collector circuitry for power-on.

3.5.2.2 Software Shutdown

The modem can be shut down via AT command by issuing the "**AT#SHDN**" command to modem. When shutting down the modem via AT command, the ON_OFF signal must not be grounded.

3.6 ON/nSLEEP

NL-SW-LTE-TCxNAG modems feature a status LED that is connected to the ON/nSLEEP signal (pin J2-3). The ON/nSLEEP pin on the modem may be used for the following functions:

- Monitor power on status of the modem
- Network status monitoring

By default the pin is configured to monitor the network status of the modem.

3.6.1 Power Status Monitoring

To configure the ON/nSleep to function as a Power Status Monitor issue the following AT commands to the modem:

```
AT#SLED=1
```

```
AT#SLEDSAV
```

3.6.2 Network Status Monitoring

To configure the ON/nSleep to function as a Network Status Monitor, issue the commands below. **Note:** This is the firmware default state for this pin.

```
AT#SLED=2
```

```
AT#SLEDSAV
```

This AT command will enable the ON/nSLEEP signal to drive the status LED with the behavior listed in the table below:

Device Status	LED Behavior
Device Off	Permanently Off
Idle, Not Registered	Permanently On
Registered in Idle, with Power Saving	Fast Blinking (blinking period depends on network status)
Registered with Full Network Service	Slow Blinking (3 second period, $T_{ON} = 1s$)

Note: The configuration of ON/nSLEEP as the status LED is not saved across resets. To save a modified configuration across reboots the "AT#SLEDSAV" command must be issued.

3.7 Firmware Updates Over the Air (FOTA)

LTE networks are constantly being updated, improved, and enhanced with new features. As a result, carriers are making frequent network changes. Most changes will not negatively affect devices connected to those networks, but occasionally an update will prevent an unprepared device from reconnecting to the network permanently.

To account for these future changes, FOTA (Firmware Over the Air) capability is being added to cellular modules by each manufacturer. NimbeLink supports this functionality in the entire Skywire family of embedded modems. Therefore, it is highly recommended that designers implement provisions to accommodate for FOTA processes.

Failure to accommodate FOTA processes may result in interruptions in cellular connectivity in the event of network changes. If a device can no longer access the network, FOTA cannot be used to remedy the problem. In this case, the only way to recover device functionality is to physically update the device firmware.

FOTA instructions are available by contacting NimbeLink's product support team at product.support@nimbelink.com.

3.8 Soldered-Down Verizon SIM

The NL-SW-LTE-TCxNAG Skywires have the ability to select between a soldered-down Verizon SIM and a conventional 3FF SIM card inserted into the SIM slot, J3.

By default the modem prioritizes the 3FF SIM card and the soldered-down SIM interface is disabled until commanded otherwise with the AT commands listed in the following sections.

3.8.1 Enabling the Soldered-Down Verizon SIM

To enable the soldered-down SIM interface, issue the following commands:

```
AT#ENSIM2=1
```

```
AT#ENHRST=1,0
```

The modem will immediately reboot after entering the last command. When the modem becomes responsive again, the soldered-down SIM interface will now be enabled. The SIM enable command and SIM selection commands will not persist across carrier firmware switches with the AT#FWSWITCH command and must be reissued after the new firmware selection is loaded.

Note 1: Even after issuing the "AT#ENSIM2=1" command and rebooting, the 3FF SIM card interface will still be activated and selected.

Note 2: The "#ENSIM2: x" setting is saved in NVM, and will persist across device resets and power-ons. Additionally, the modem must reboot in order to save any changes made to this setting.

3.8.2 Swapping Between SIM Interfaces During Operation

After enabling the soldered-down SIM interface, it is possible to swap between the 3FF SIM card and the soldered-down SIM at will while the modem is powered on.

To instruct the modem to use the soldered-down SIM, issue the following AT commands:

```
AT+CFUN=4
AT#HSEN=1
AT#ENSIM2=1
AT#SIMSELECT=2
AT+CFUN=1
```

To instruct the modem to use the 3FF SIM Card in the SIM slot, issue the following AT commands:

```
AT+CFUN=4
AT#HSEN=1
AT#SIMSELECT=1
AT+CFUN=1
```

Note 1: Be sure to issue "AT+CFUN=4" each time before swapping the active SIM. This will allow the modem to gracefully detach from the network before swapping its SIM.

Note 2: The "#SIMSELECT:" setting is saved in NVM, and will persist after device resets and power-ons.

3.8.3 Disabling the Soldered-Down Verizon SIM Interface

If desired, the soldered-down SIM interface can be disabled using the following commands:

```
AT#ENSIM2=0
AT#ENHRST=1,0
```

The modem will immediately reboot after entering the last command. When the modem becomes responsive again, the soldered-down SIM will now be disabled.

Note 1: After issuing the "AT#ENSIM2=0" command, the modem will set its SIM selection state to: "#SIMSELECT: 1"

Note 2: The "#ENSIM2: x" setting is saved in NVM, and will persist across device resets and power-ons. Additionally, the modem must reboot in order to save any changes made to this setting.

3.9 Dual-Image Firmware Information

3.9.1 Overview

The NL-SW-LTE-TCxNAG modems have a dual-image firmware that allows the user to switch between Verizon and AT&T firmware images. These firmware images are swapped using the "AT#FWSWITCH" command.

Note: When swapping the active firmware image, the selection can be made to persist after reset by storing it in Non-Volatile Memory (NVM). See the commands below.

Note: Issuing the "AT#FWSWITCH" command performs a factory reset on the target firmware image. Any AT commands previously set, including but not limited to setting the APN and enabling and setting the second SIM interface, will need to be issued again once the firmware switch is complete.

3.9.2 Selecting the AT&T Image

To activate the AT&T configuration, issue one of the following AT commands:

```
AT#FWSWITCH=0,0 // Swap to AT&T image, Do not save choice to NVM
```

```
AT#FWSWITCH=0,1 // Swap to AT&T image, Save choice to NVM
```

After entering one of the above commands, the modem will restart, and boot up with the new firmware configuration.

3.9.3 Selecting the Verizon Image

To activate the Verizon configuration, issue one of the following AT commands:

```
AT#FWSWITCH=1,0 // Swap to Verizon image, Do not save choice to NVM
```

```
AT#FWSWITCH=1,1 // Swap to Verizon image, Save choice to NVM
```

After entering one of the above commands, the modem will restart, and boot up with the new firmware configuration.

3.10 GNSS

The NL-SW-LTE-TCxNAG Skywires feature a built-in GNSS system that is capable of receiving the entire spectrum of GNSS systems available, including GPS, GLONASS, BeiDou, Galileo, and QZSS.

An active GNSS antenna must be used with the NL-SW-LTE-TCxNAG Skywires. The requirements for the GNSS antenna are available in [Section 3.10.1](#).

3.10.1 GNSS Antenna Requirements

It is required to use an active GPS antenna with the following specifications:

Item	Value
Antenna Type	GPS only
Antenna Gain	17 dB (typical)
Operating Voltage	3.3 VDC
Maximum Current	100 mA

Applications utilizing GLONASS require a GNSS pre-filter with the following specs:

Item	Value
Characteristic Impedance	50 Ω
Insertion Loss (1575.42–1576.42 MHz)	1.4 dB (max)
Insertion Loss (1565.42–1585.42 MHz)	2.0 dB (max)
Insertion Loss (1597.5515–1605.886 MHz)	2.0 dB (max)

3.10.2 Active GNSS Antenna Control

A 3.3 VDC, 100 mA LDO regulator is available on the Skywire, and can be used to supply power to an external active GNSS antenna.

Control of the power supply for the active GNSS antenna is managed using GPIO5 on the modem. To conserve power, this regulator is turned off by default.

To turn on the regulator and power the external active GNSS antenna, issue one of the following commands to the modem.

```
AT#GPIO=5,1,1,0 // Turn on GPS, GPIO state will not persist after reset
```

```
AT#GPIO=5,1,1,1 // Turn on GPS, GPIO state will persist after reset
```

To disable the power to the external GNSS antenna, issue one of the following commands to the modem:

```
AT#GPIO=5,0,1,0 // Turn off GPS, GPIO state will not persist after reset
```

```
AT#GPIO=5,0,1,1 // Turn off GPS, GPIO state will persist after reset
```

3.11 Cellular Antenna Requirements

The NL-SW-LTE-TCxNAG Skywire modems support a primary cellular antenna connection, and a diversity antenna connection. These connectors are U.FL connectors, and are labeled as X1 and X2, respectively.

The modem's primary antenna interface, X1, supports both TX and RX communication. The diversity antenna interface is an input for a second Rx antenna to improve radio sensitivity. According to carrier requirements, both the primary and the diversity antenna must be implemented.

Note: Many antennas require the use of a U.FL to SMA cable, such as the [Taoglas CAB.011](#).

3.11.1 Primary Antenna Requirements

Section 3.10.1 contains the requirements for the chosen primary antenna. Follow these requirements closely in order to ensure ideal modem operation, and to avoid potential damage to the Skywire during operation.

Required Primary Antenna Specifications	
Impedance	50 Ω
Gain	< 3 dBi
Input Power	\geq 24 dBm Average Power
VSWR Absolute Max ¹	\leq 10:1
VSWR Recommended ²	\leq 2:1

1. Limit to avoid permanent damage
2. Limit to fulfill all regulatory requirements

3.11.2 Diversity Antenna Requirements

The table below contains required specifications for the diversity antenna.

Required Diversity Antenna Specifications	
Impedance	50 Ω
VSWR Recommended ¹	\leq 2:1

1. Limit to obtain maximum sensitivity

3.11.3 Antenna Placement

The modem's cellular antenna placement will directly affect the modem's performance. It is vital that system designers carefully consider the placement of the antenna and follow all of the guidelines and specifications set by the antenna manufacturer. The following guidelines are general recommendations for antenna installation:

- The antenna must have an impedance of 50 ohms.
- Keep the antenna cable as short as possible.
- The antenna must not be installed inside a metal enclosure, nor near metal objects unless specified by the antenna manufacturer.
- The antenna must be installed according to the manufacturer's instructions.
- Antenna gain must not exceed the values indicated in the regulatory requirements in [Section 5.7](#).
- Antenna integration should optimize antenna efficiency. Antennas are recommended to have >50% efficiency on all frequency bands.
- Antenna should not be mounted near noisy EM devices.

3.11.4 Recommended Antennas

While Skywire modems will work with antennas from other manufacturers, the following antennas have been designed specifically to work with Skywire.

Type	Manufacturer	Part Number
Internal Cellular Antenna	Airgain	F47AGBWA-G150U
External Cellular Antenna ¹	Airgain	ET56AGBJA

1. U.FL to SMA adapter required.

3.12 Skywire Reference Design

NimbeLink offers free reference schematic and layout files as examples of how to integrate Skywire modems into various systems. Schematics, design files, gerber files, and tutorials for a variety of different systems can be found on the Skywire Development Kits webpage: <https://nimbelink.com/development-kits/>

4. Mounting Guidelines

Skywire cellular modems support multiple connection methods. The two primary methods are board-to-board connectors and soldering directly to the baseboard.

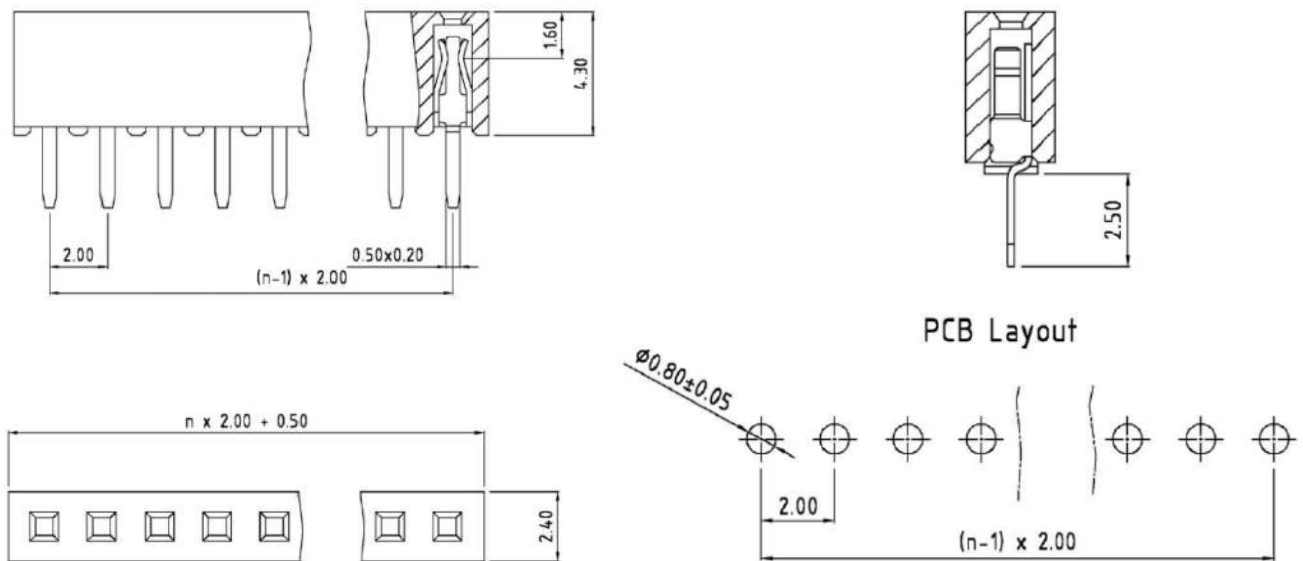
4.1 Board-to-Board Connectors Approach

The Skywire interface calls for two 10-pin, 2mm pitch, female receptacles spaced 22 mm apart. There are many connector manufacturers that can be used. Below is one readily available product:

Manufacturer: Sullins Connector Solutions

Part Number: NPPN101BFCN-RC

Typical part drawing and footprint information for the NPPN101BFCN-RC connector:



4.1.1 Mechanical Retention

Certain applications where the modem is mounted on the host board using the connector approach detailed in Section 4.1 may need to mechanically secure the Skywire modem and its SIM card in order to prevent the modem from vibrating out of the mating connectors.

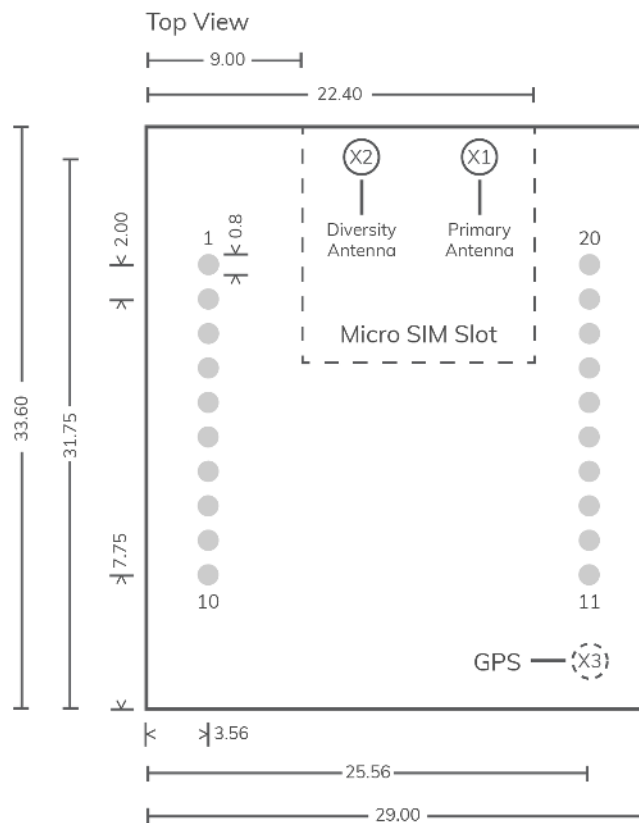
Skywire modems do not have any dedicated attachment points for securing to the host board, however it can easily be secured by one of the following methods:

- Zip ties
- Foam tape mounted on the Skywire to press against the enclosure
- Mechanical retention of the modem and SIM by the enclosure (example below)
 - https://nimbelink.com/Documentation/Skywire/1001460_Mechanical_Retention_Enclosure.pdf
- Solder the Skywire to the host board (as described in Section 4.2)

4.2 Solder to Board Connection

Skywires can be soldered directly to a PCB. The PCB should be designed with two rows of ten 0.8mm plated through holes spaced 2mm apart. The two rows should be 22mm apart. See the figure below for the recommended footprint.

All measurements are in millimeters. U.FL locations are marked with circles, X1 and X2 are on the top of the board. J3 is the Micro SIM card slot on the bottom side of the board.



5. Regulatory Information

5.1 FCC & IC Compliance

If the modem's antenna is located farther than 20cm from the human body and there are no adjacent transmitters, the FCC/IC approvals of the on-board Telit LE910C4-NF or Telit LE910C1-NF cellular module can be reused by the end product.

Should the modem's antenna be mounted closer than 20cm from the human body or if there are adjacent transmitters, additional FCC/IC testing may be required for the end product.

NL-SW-LTE-TCxNAG modems make use of the on-board Telit LE910Cx-NF module's FCC & IC identification numbers. The TC1NAG and TC4NAG both share the same FCC ID and IC ID numbers:

Orderable Device	FCC ID	IC ID (certification number)
NL-SW-LTE-TC4NAG NL-SW-LTE-TC1NAG	RI7LE910CXNF	5131A-LE910CXNF

The FCC certificate is available at the following link by searching for the FCCID listed above: <https://www.fcc.gov/oet/ea/fccid>

The IC ID certificate is available at the following link by searching for the IC ID listed above:
<https://sms-sgs.ic.gc.ca/equipmentSearch/searchRadioEquipments?execution=e1s1&lang=en>

5.2 Regulatory Certifications

Certification	NL-SW-LTE-TC1NAG	NL-SW-LTE-TC4NAG
FCC ID	RI7LE910CXNF	RI7LE910CXNF
IC ID	5131A-LE910CXNF	5131A-LE910CXNF
PTCRB	In Progress	Complete

5.3 Carrier Specific Certifications

Certification	NL-SW-LTE-TC1NAG	NL-SW-LTE-TC4NAG
AT&T	In Progress	Complete
Verizon	In Progress	Complete

5.4 Export Control Classification Number (ECCN)

ECCNs are five character alphanumeric designations used on the Commerce Control List (CCL) to identify dual-use items for export control purposes. An ECCN categorizes items based on the nature of the product, i.e. type of commodity, software, or technology and its respective technical parameters.

ECCN for All Skywire Modems: 5A992.c

5.5 Harmonized Tariff Schedule Code

HTS Code: 8517.62.0010

5.6 Interference statement

This device complies with Part 15 of the FCC Rules and Industry Canada licence-exempt RSS standards. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

5.7 Wireless Notice

In order to maintain FCC/IC radiation exposure limits set forth for an uncontrolled environment alongside carrier specific certifications the antennas cannot exceed the maximum gain levels listed here:

Band	Frequency	Max Antenna Gain
B2	1900 MHz	8.01 dBi
B4	1700 MHz	5.00 dBi
B5	850 MHz	6.12 dBi
B12	700 MHz	5.63 dBi
B13	700 MHz	5.94 dBi
B14	700 MHz	5.94 dBi
B71	600 MHz	5.63 dBi

5.8 Modification Statement

Nimbelink has not approved any changes or modifications to this device by the user. Any changes or modifications could void the user's authorization to operate the equipment.

5.9 End Product Labeling Requirements

End products utilizing NL-SW-LTE-TCxNAG modems should be labeled with the following information:

TC4NAG:

Device Uses Approved Radio: NL-SW-LTE-TC4NAG

Contains FCC ID: RI7LE910CXNF

Contains IC: 5131A-LE910CXNF

This device complies with Part 15 of the FCC Rules and Industry Canada licence-exempt RSS standards. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

TC1NAG:

Device Uses Approved Radio: NL-SW-LTE-TC1NAG

Contains FCC ID: RI7LE910CXNF

Contains IC: 5131A-LE910CXNF

This device complies with Part 15 of the FCC Rules and Industry Canada licence-exempt RSS standards. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

6. Document Version Information

Revision	Description	Date
6	<ul style="list-style-type: none"> - Created Document Version Information Section - Added links to Skywire Hardware Design Guide and Checklist to section 3. - Added note to recommend checking for new versions to section 1.1. 	07/21/2020
7	<ul style="list-style-type: none"> - Changed reboot command in section 3.8.1 to AT#ENHRST. 	07/21/2020
8	<ul style="list-style-type: none"> - Added note about ON_OFF timing. 	07/29/2020
9	<ul style="list-style-type: none"> - Changed the AT#ENHRST command in Section 3.8.1 to "AT#ENHRST=1,0" - Changed the AT#REBOOT command in Section 3.8.3 to "AT#ENHRST=1,0" 	08/13/2020
10	<ul style="list-style-type: none"> - Added max ripple voltage recommendation 	8/31/2020
11	<ul style="list-style-type: none"> - Added note about AT#FWSWITCH and AT command settings 	09/29/2020
12	<ul style="list-style-type: none"> - Updated copyright year. - Updated section 3.8 with SIM selection across firmware selection information. - Fixed USB section spacing issue. 	02/05/2021
13	<ul style="list-style-type: none"> - Updated antennas 	06/17/2021
14	<p>Added the TC1NAG modem. Changes include:</p> <ul style="list-style-type: none"> - Added a link to the TC1NAG product page in Section 1.4. - Added a note about TC1NAG power numbers in Section 2.2.4. Power testing for the TC1NAG is in progress as of Sept. 2021. - Added in theoretical max downlink/uplink speeds for the TC1NAG in Section 2.3.3. - Updated language throughout the document referencing the only the TC4NAG to "TCxNAG" to account for both modems. - Updated regulatory information in Section 5 to include the TC1NAG. - Removed Telus and Rogers certification statuses from the TC4NAG. NimbeLink is not pursuing those certifications at this time. Contact sales@nimbelink.com for more information. 	09/20/2021