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NEO modules

TCXO-to-crystal migration guide

Application note

Abstract

This document provides options and guidelines for migrating TCXO-based NEO modules to crystal-based NEO modules. The application note also explains the potential impact on GNSS performance and other possible hardware/firmware concerns.

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Contents

1 Introduction

This application note describes the migration procedure from TCXO-based NEO modules to crystal-based NEO variants.

The main difference between TCXO and crystal variants is basically the type of oscillator used. The small difference in the internal oscillator leads to some considerations described in this document. For example, the frequency tolerance of crystals is wider than that of TCXOs. This means that the receiver must search over a wider range of frequencies, which will extend the time-to-first-fix especially in weak signal conditions.

In addition, the crystal's frequency is highly sensitive to temperature-variant environments. Therefore, the operating temperature, as well as heat dissipating systems on the board need to be taken into consideration.

Nevertheless, with proper adjustments and design guidelines, crystal-based GNSS receivers can achieve very similar performance to a TCXO-based solution and are thus worth considering as a good alternative for many applications.

This document focuses on TCXO-based NEO-M8Q, NEO-M8N, NEO-8Q, and NEO-7N modules.

☞ This document is still under development. New or additional information (e.g. test data) might be added in the future.

2 Generic guidelines

Generally, every migration requires different considerations for each dedicated product. However, there are a few parameters that are generic to all NEO modules. One is the presence of an SAW filter and a good LNA in the RF front-end, and the second is the effect of the temperature and how to mitigate it.

2.1 RF design

Performance of crystal-based designs strongly depends on the GNSS signal power levels. Under strong signal reception, crystal-based modules can perform as well as their equivalent TCXO versions. Therefore, for designs without an external LNA or using a passive antenna, it is recommended to include an external LNA before the crystal-based NEO module, especially in applications under difficult GNSS visibility or poor reception. If, in addition, strong out-of-band jammers are close to the GNSS antenna (for example, a cellular antenna), an additional SAW filter and even notch filters[1] in front of the LNA might be needed.

Applications with an active antenna or a present external LNA are exempt from RF front-end redesign.

Refer to the relevant hardware integration manual for more guidelines on passive antenna designs and recommended LNA/SAW components: NEO-8Q/M8 Hardware Integration Manual [1] and NEO-7 Hardware Integration Manual [2].

2.2 Temperature

The frequency drift for crystal and TCXO oscillators is both very dependent on the ambient temperature. Although the receiver can correct such an offset, it is recommended to avoid quick temperature changes. As a brief explanation, a GNSS receiver can track satellite signals up to a

[1] As an example, NEO-M9N shows a very good immunity against cellular signal due to its notch filter for the LTE band 13, which operates at 780 MHz.

certain high dynamic value, which is defined as Delta frequency / Delta time (Δf/Δt). As a result, temperature change in a very short time at the oscillator will end in a very high dynamic, in the worst scenario losing phase lock.

Although both TCXO and crystal are very sensitive to ambient temperature changes, due to the wider frequency range of crystals compared to TCXO, special attention is needed for crystal-based designs.

If the receiver is possibly placed under these conditions, it is highly recommended to isolate the module thermally by minimizing thermal conduction over the PCB, and to place the module far from fans or other components with quick body temperature change that can increase the board and ambient temperature. Adding elements for heat dissipation between the receiver and other elements as well as increasing the surface contact area of the board around stabilizes the temperature.

The effect of the temperature on the crystal can be seen in Figure 1 below, with NEO-M8M as an example. As shown in Figure 1, u-blox modules can easily re-adjust the frequency drift for normal operation. It is important to mention that all crystal oscillators qualified by u-blox pass extensive tests to ensure such smooth frequency drift over full operation temperature range (-40 to +85 °C).

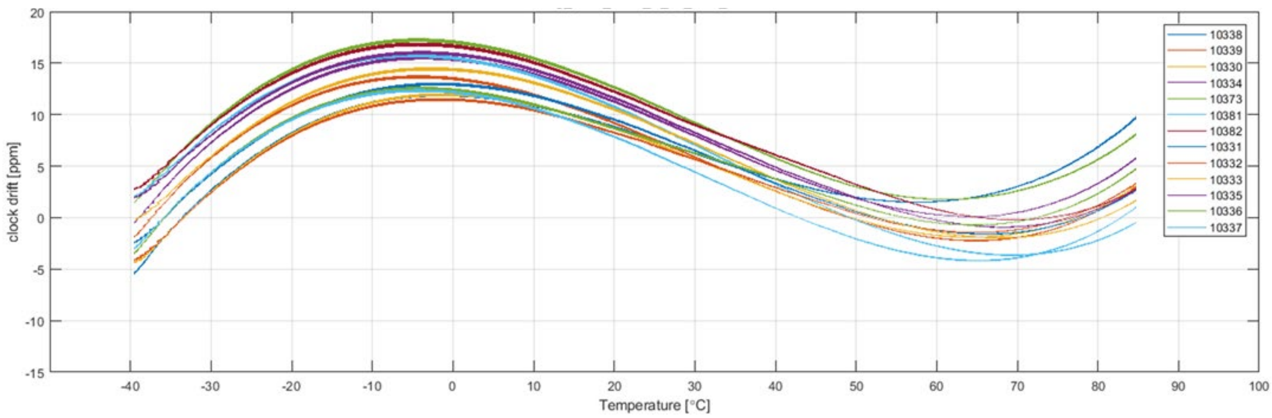


Figure 1: Temperature effect on NEO crystal-based modules

3 NEO-M8(Q/N)

The only difference between the NEO-M8Q and the NEO-M8N is the integrated flash memory. For this reason, this chapter describes the migration of TCXO-based NEO-M8Q/M8N to crystal-based modules.

The NEO-M8M or NEO-M8J are possible options when migrating from TCXO-based NEO-M8Q/NEO-M8N to a crystal-based NEO module. Compared to the NEO-M8Q/N modules, the crystal-based NEO-M8M has no flash or no SAW + LNA, while the crystal-based NEO-M8J has integrated flash and integrated SAW+LNA, as shown in Table 1.

3.1 NEO-M8(Q/N) vs. NEO-M8(M/J)

The table below summarizes the specifications to be considered during the migration.

Field	Parameter	NEO-M8Q	NEO-M8N	NEO-M8M	NEO-M8J
HW	**Oscillator**	TCXO	TCXO	Crystal	Crystal
	Interface config.	Same	Same	Same	Same
	Pinout	Same	Same	Same[2]	Same
	Flash memory	None	Yes	None	Yes
RF design	**Front-end**	Integrated SAW + LNA	Integrated SAW + LNA	No integrated SAW and LNA. With passive antenna, an external LNA is **recommended**. SAW filter is optional.	Integrated SAW[3] + LNA
	Out-of-band immunity	Good	Good	Poor	Good
Temp.	**Storage temp. °(C)**	Max +85	Max +85	Max +105	Max +85
	Thermal isolation[4]	Recommended	Recommended	Highly recommended	Highly recommended
Power Req.	**Supply (Vcc & Vio) (V)**	[2.7 - 3.6]	[2.7 - 3.6]	[1.65 - 3.6]	[2.7 - 3.6]
	Supply current (mA)	28	30	21	29
	SW backup current (mA)	Same	Same	Same	Same
	HW backup current (mA)	Same	Same	Same	Same
Sensitivity	**Dynamic Tracking (dBm)**	-167	-167	-164	-164
	TTFF (sec)[5]	Same	Same	Same	Same
SW	Firmware	ROM SPG 3.01	Flash FW SPG 3.01	ROM SPG 3.01	Flash FW SPG 3.05[6]
	Max navigation rate (Hz)	10	5	10	5
	External LNA control	Yes	Yes	None	Yes

Table 1: NEO-M8(Q/N) to NEO-M8(M/J) migration comparison (default mode: GPS & GLONASS including QZSS, SBAS)

☞ When migrating to crystal-based NEO-M8M or NEO-M8J module, make sure the receiver is not operated in Galileo-only mode. Crystal variants are not suitable for Galileo-only operation due to worse performance (TTFF, sensitivity), as documented in the NEO-M8 Data sheet [3].

[2] LNA_EN pin is reserved in NEO-M8M. In case this pin is used to switch external LNA on/off, see section 3.5.
[3] The NEO-M8J integrates an SAW filter with better out-of-band immunity than in NEO-M8(Q/N).
[4] Mainly for applications where the GNSS module is under thermal activity on the board.
[5] Cold and hot start under good GNSS visibility and using power levels of -130 dBm.
[6] For details refer to GNSS FW SPG3.05 Release notes [8].

3.2 Power requirements

Crystal-based NEO-M8M allows a wider voltage supply range. This is because of the lower voltage required by the crystal. Nevertheless, the products have overlapping operational voltage ranges.

The NEO-M8M has a lower current consumption compared to NEO-M8Q and NEO-M8N modules. This is mainly because the crystal-based NEO-M8M does not have an integrated LNA and flash memory.

Table 2 below shows the expected current drawn from NEO-M8(Q/N) and NEO-M8(M/J). More information is available in the NEO-M8 Data sheet [3].

Parameter	Symbol	Conditions	Module	Typ. GPS & GLONASS	Typ. GPS / QZSS /SBAS	Units
Average supply current [7]	Icc Acquisition mA [8]	VCC_IO = VCC = 3 V	NEO-M8N	32	25	mA
			NEO-M8Q	30	24	mA
			NEO-M8M	24	19	mA
			NEO-M8J	31	24	mA
	Icc Tracking (Continuous mode)	VCC_IO = VCC = 3 V	NEO-M8N	30	23	mA
			NEO-M8Q	28	23	mA
			NEO-M8M	21	17	mA
			NEO-M8J	29	23	mA
	Icc Tracking (Power save mode / 1 Hz)	VCC_IO = VCC = 3 V	NEO-M8N	13	12	mA
			NEO-M8Q	11.5	11.1	mA
			NEO-M8M	5.3	4.8	mA
			NEO-M8J	12	11	mA
Backup battery current [9]	I_BCKP	HW backup mode, VCC_IO = VCC = 0 V V_BCKP =1.8 V	NEO-M8N NEO-M8Q NEO-M8M NEO-M8J		15	µA
SW backup current	I_SWBCKP	SW backup mode, VCC_IO = VCC = 3 V	NEO-M8N NEO-M8Q NEO-M8M NEO-M8J		30	µA

Table 2: NEO-M8(Q/N) and NEO-M8(M/J) power requirements

For those applications that wait for the initialization message to start the operation at the startup, note that the delta time may vary when migrating to NEO-M8(M/J). The variation, in the order of 100 ms, occurs especially when the voltage ramp is slow, and the BBR memory is not maintained alive (no external backup supply).

Note that initial configuration time might be increased due to longer bootup time of crystal-based NEO-M8M/J. The maximum time difference seen between TCXO and crystal variants during start up is 600 ms.

Contact u-blox technical support if this may affect your application.

[7] Simulated constellation of 8 satellites is used. All signals are at -130 dBm. VCC= 3 V.
[8] Average current from startup until the first fix.
[9] Use this figure to determine the required battery capacity.

3.3 Out-of-band immunity

The NEO-M8J and the NEO-M8M differ in their RF design, which highly impacts the immunity, and, as a consequence, the performance.

3.3.1 NEO-M8M

As mentioned earlier, the crystal-based NEO-M8M is the optimized version for cost-sensitive applications. This is achieved by placing a crystal instead of a TCXO oscillator and the absence of an SAW and LNA inside the module.

Both NEO-M8Q and NEO-M8N include an SAW filter as the first element in the RF path that strongly attenuates other signals coupled into the RF signal. Such filtering is important on applications exposed to strong jamming environments or that incorporate cellular antennas. The SAW filter is followed by an LNA[10], which will amplify the filtered signal and forward it to the chip.

During the migration process, it is important to determine if the device will be under strong RF interference sources. In that case, placing a GNSS SAW filter in the front might significantly improve the performance. Note that if these filters are not ideal, a small attenuation at the GNSS bands will be present. Refer to the NEO-8Q/NEO-M8 Hardware Integration Manual [1] for a selection of suitable filters and LNAs for out-of-band immunity mitigation.

3.3.2 NEO-M8J

The crystal-based NEO-M8J, on the other side, has the same RF architecture as the TCXO-based NEO-M8Q and NEO-M8N. One of the additional advantages when migrating to the NEO-M8J is the improved immunity offered by the SAW filter. The table below offers a quick summary of both filters' characteristics.

Attenuation (dB)	SAW filter in NEO-M8(Q/N)	SAW filter in NEO-M8J
... - 925 MHz	30	47
1427 – 1463 MHz	35	48
1710 – 1980 MHz	30	51
2400 – 2570 MHz	33	40
2570 – 3000 MHz	38	40

Table 3: Attenuation in dBs at the different frequencies for the SAW filters in NEO-M8(Q/N/J)

For those applications using cellular antennas and/or RF, interferences are likely to be coupled into the RF input line, the signal quality will be improved, and, consequently, the overall performance.

3.4 Internal flash memory

The NEO-M8Q and the NEO-M8M are both ROM-based modules. Therefore, no variation in the application or in production when migrating NEO-M8Q to NEO-M8M is needed. However, the NEO-M8N includes a 16-Mbit SQI flash memory, which might have an important impact in the device operation if flash is not present when migrating to the NEO-M8M.

The programmable flash memory allows to save the configuration permanently, update the FW, data logging, and store long-term orbit data for a faster position fix. The lack of the memory can be resolved if:

1. The data is saved at the host side and sent it to the receiver at each start up, as in AssistNow Offline.

[10] The importance of the LNA for a crystal module has been explained in the previous section.

2. The host sends the configuration messages to the receiver at each startup. In case this configuration is just the communication baud rate, it can be permanently saved in the OTP memory (eFused bits).
3. An external backup battery or external supply at V_BCKP pin keeps the BBR (battery-backed RAM) alive.

In addition, flash also provides the upgradability of the FW. However, considering the maturity of the ROM SPG 3.01 and that no further FW releases are expected, migrating from flash-based NEO-M8N to ROM-based NEO-M8M does not cause any extra concern.

☞ The crystal-based NEO-M8J contains a flash memory, allowing straightforward and easy migration from TCXO-based NEO-M8N.

3.5 LNA_EN feature

The NEO-M8Q and NEO-M8N can switch an optional external LNA on/off when entering power save modes. Note that this feature is not present in the crystal-based NEO-M8M, and that the pin is reserved.

In case this feature is wanted, it can be implemented on the host processor side, which most likely requires redesign.

☞ The NEO-M8J has this LNA-EN feature available as TCXO-based NEO-M8Q and NEO-M8N.

3.6 Performance

It is important to mention that our test sites use an LNA followed by an attenuator after the simulator. Thus, the signal is attenuated to reach different power levels. This setup simulates those designs where the receiver is either using an active antenna, or an external LNA in combination with a passive antenna.

Consequently, the NEO-M8M sensitivity and TTFF values shown in section 3.6.1, as well as the road test performance of NEO-M8M (section 3.6.2) can be extrapolated to the NEO-M8J. Both crystal-based modules are expected to behave similarly under these conditions.

However, if the application just integrates a passive antenna, the LNA inside the NEO-M8J will be the key element for a good performance. In addition, the SAW filter, present in the NEO-M8N/NEO-M8Q and NEO-M8J, provides excellent immunity against out-of-band jammers.

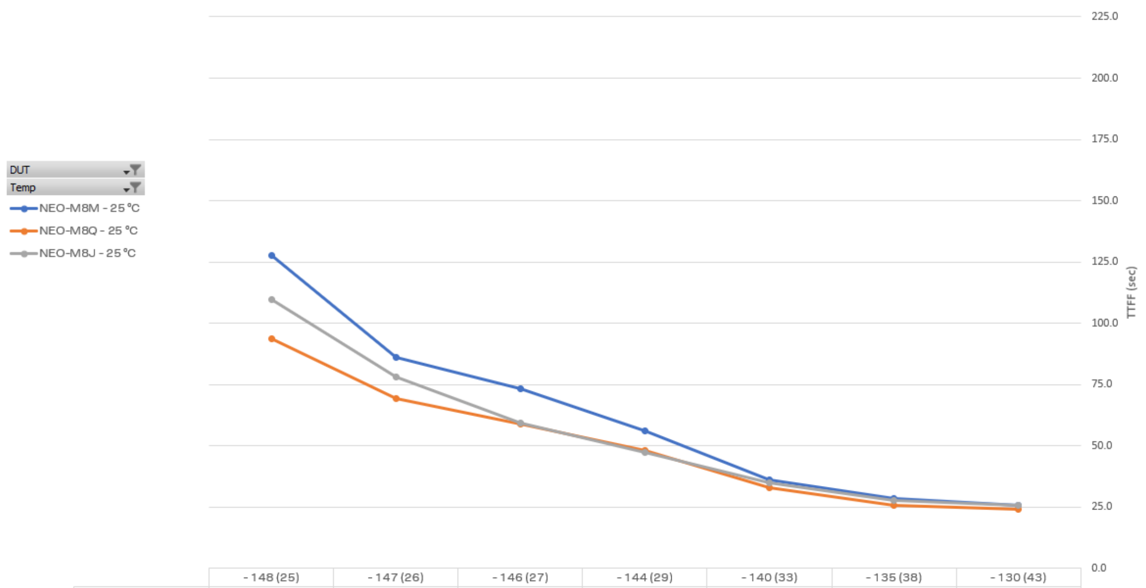
The crystal-based NEO-M8J with integrated flash and SAW+LNA, is the perfect and easy migration option for the TCXO-based NEO-M8N/NEO-M8Q, which shows good performance under all signal power levels.

The NEO-M8M, on the other hand, would need an external LNA or an active antenna when the signal is weak to ensure good performance (as mentioned in section 2.1).

3.6.1 Startup sensitivity and TTFF

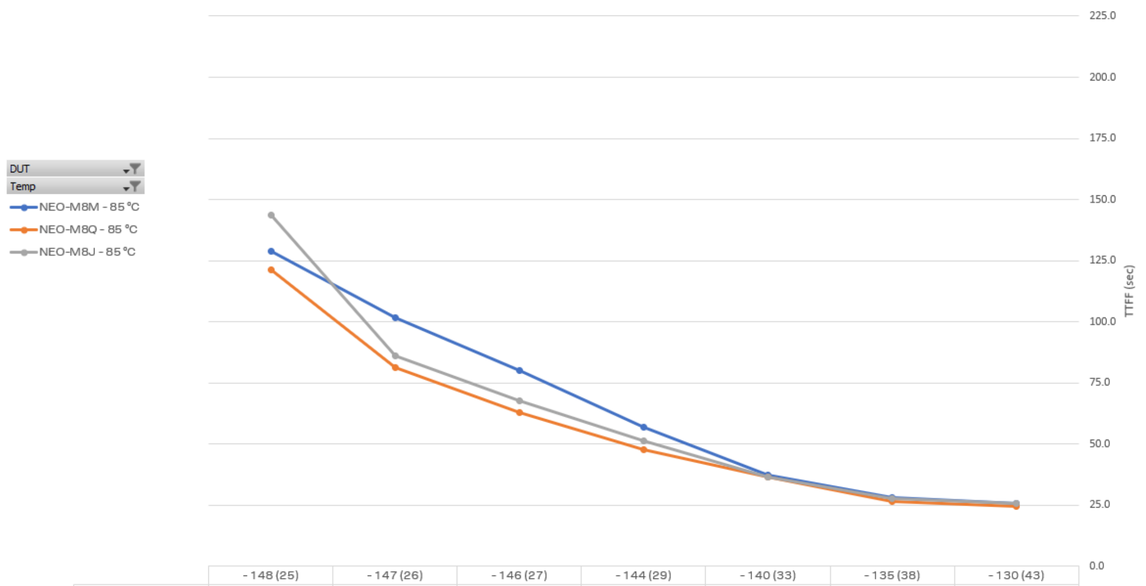
Crystal-based GNSS receivers are characterized as having a longer time to synchronize with GNSS signals. The effect is more visible when the signals are weak and the GNSS visibility is poor.

Such behavior can be seen in Figure 2 where the times to fix of crystal-based NEO-M8(M/J) become longer than those of TCXO-based NEO-M8Q as the GNSS signal power drops.



	-148 (25)	-147 (26)	-146 (27)	-144 (29)	-140 (33)	-135 (38)	-130 (43)
NEO-M8M - 25 °C	127.56	86.07	73.34	55.88	36.04	28.60	25.76
NEO-M8Q - 25 °C	93.63	69.40	58.76	47.91	32.79	25.55	24.19
NEO-M8J - 25 °C	109.46	77.90	59.34	47.18	34.74	27.78	25.66

Figure 2: TTFF vs. signal power in dBm and equivalent C/N0 inside parenthesis for NEO-M8Q, NEO-M8M and NEO-M8J during cold starts[11] (default mode: GPS & GLONASS including QZSS, SBAS)



	-148 (25)	-147 (26)	-146 (27)	-144 (29)	-140 (33)	-135 (38)	-130 (43)
NEO-M8M - 85 °C	128.85	101.58	80.09	56.85	37.16	27.90	25.54
NEO-M8Q - 85 °C	121.34	81.11	62.81	47.57	36.38	26.37	24.28
NEO-M8J - 85 °C	143.73	86.21	67.77	51.28	36.53	27.72	25.76

Figure 3: TTFF vs. signal power in dBm and equivalent C/N0 inside parenthesis for NEO-M8Q, NEO-M8M and NEO-M8J during cold starts[11] (default mode: GPS & GLONASS including QZSS, SBAS) at 85°C

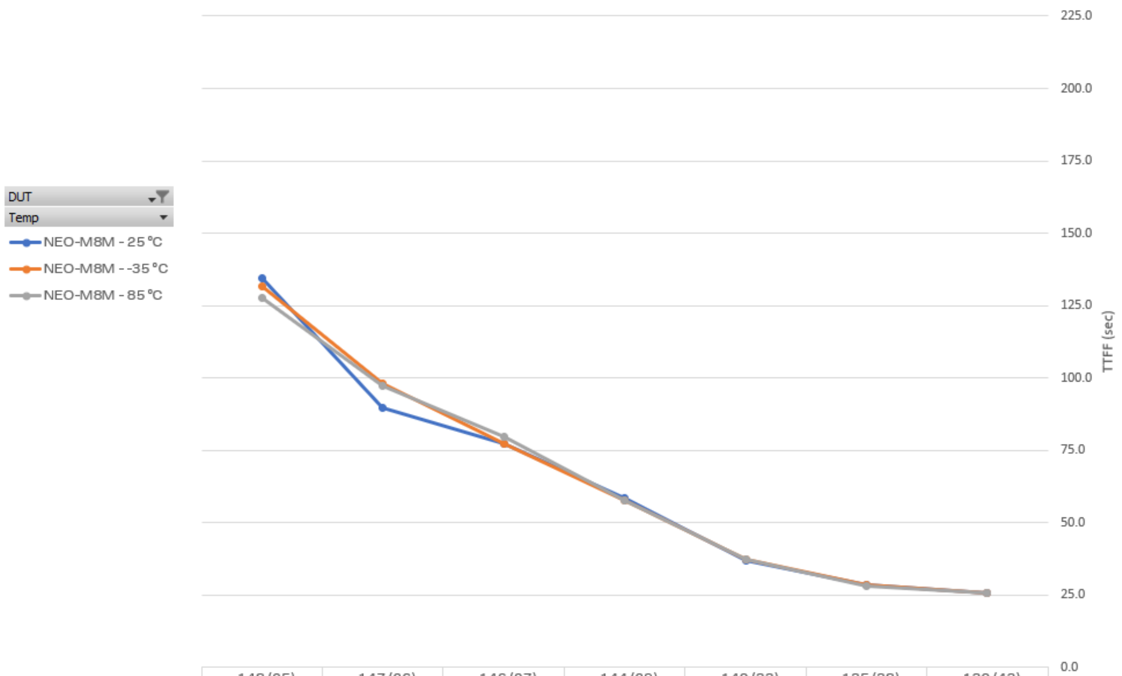
In general, a strong signal will give the shortest time-to-first-fix. As shown in Figure 2 (at room temperature +25 °C) and Figure 3 (at high temperature +85 °C), the TTFF differences between the NEO-M8Q (orange line) and the crystal variants NEO-M8M (blue line) and NEO-M8J (grey line) grow as the GNSS signal levels drop. Between the crystal-based NEO variants, the cold start performance of the NEO-M8J (integrated SAW+LNA) shows better performance than the NEO-M8M, especially at weak signals environment. Figure 2 and Figure 3 also show that under a strong signals environment

[11] Results obtained on our test sites using a good LNA in front and an attenuator to decrease power level.

(signals with active antenna), the TTFF is very similar for both TCXO and crystal-based NEO products at different temperatures.

The GNSS signal power levels above 43 dBHz (-130 dBm) are considered as strong signals. The cold start results in Figure 2 and Figure 3 show that the TTFF numbers of all TCXO and crystal-based NEO variants are still very close to each other even at weaker signal condition of 33 dBHz (-140 dBm). Such Carrier-to-Noise ratio (C/N0) levels should be achievable with good open-sky visibility (best to have the satellite at the Zenith) using an active antenna.

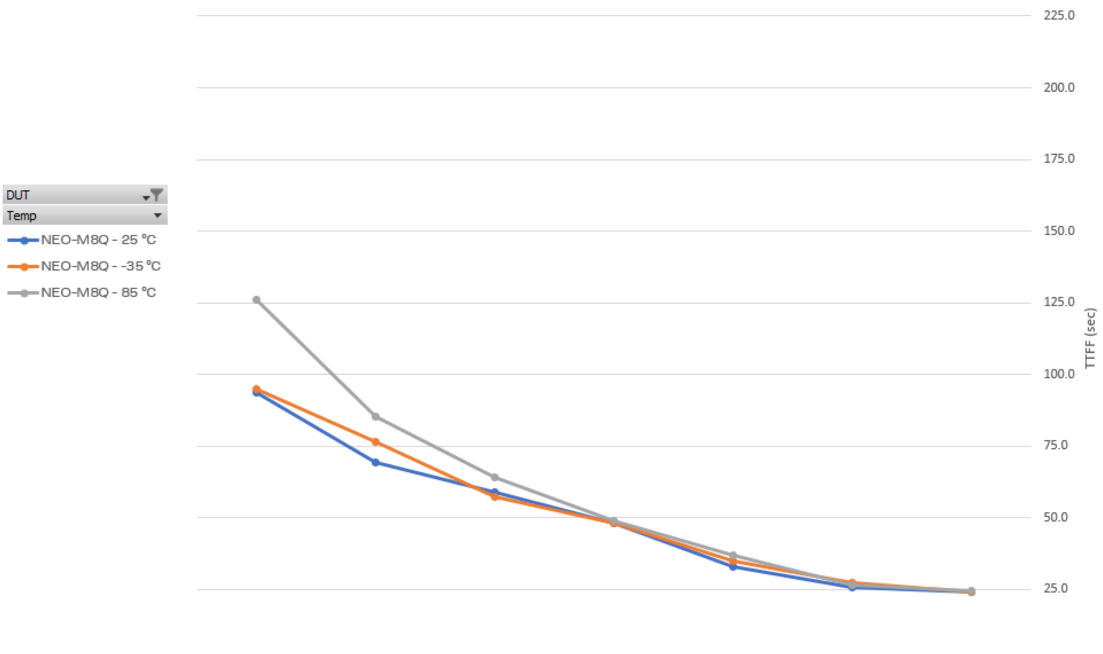
For most crystal-based GNSS receivers, TTFFs degrade with weak signals and at the limits of the operating temperatures, -40 and +85 °C, as mentioned in section 2.2. As an example, a receiver which starts at -35 °C will gradually increase the crystal temperature due to both components' proximity (self-heating), which results in an increase of the clock drift during the acquisition of the GNSS signals. Nevertheless, the NEO-M8M has shown very good behavior under those temperatures as shown in Figure 4. Again, the variability associated is not relevant when GNSS signals are strong enough, as can be seen in the figure below.



	- 148 (25)	- 147 (26)	- 146 (27)	- 144 (29)	- 140 (33)	- 135 (38)	- 130 (43)
NEO-M8M - 25 °C	134.42	89.61	77.37	58.47	36.66	28.59	25.82
NEO-M8M - -35 °C	131.41	97.91	77.19	57.68	37.09	28.41	25.62
NEO-M8M - 85 °C	127.45	97.41	79.60	57.47	37.26	27.89	25.57

Figure 4: TTFF vs. signal power in dBm and equivalent C/N0 inside parentheses for NEO-M8M during cold starts at +25, -35, and +85 °C

For TCXO-based NEO-M8Q and NEO-M8N modules we see a similar expected behavior: TTFFs of NEO-M8Q/N stay faster than those of crystal-based NEO-M8M in all temperature ranges, as shown in Figure 5.



	- 148 (25)	- 147 (26)	- 146 (27)	- 144 (29)	- 140 (33)	- 135 (38)	- 130 (43)
NEO-M8Q - 25 °C	93.63	69.40	58.76	47.91	32.79	25.55	24.19
NEO-M8Q - -35 °C	94.90	76.26	57.22	47.95	34.66	27.35	24.21
NEO-M8Q - 85 °C	126.17	85.30	64.20	48.65	36.63	26.44	24.31

Figure 5: TTFF vs. signal power in dBm and equivalent C/N0 inside parentheses for NEO-M8Q/N during cold starts at +25, -35, and +85 °C

As a summary, the longer TTFFs induced by the crystal's wider drift and the extreme operating temperature can be easily mitigated by using a good GNSS antenna or LNA. Under such good GNSS signal conditions, we can predict a signal power level above -144 dBm, where both TCXO and crystal variants show similar TTFF values. As mentioned in section 2.1, an external LNA is recommended when using a passive antenna with NEO-M8M.

3.6.2 Road test performance analysis

Road tests shows real behavior in dynamic scenarios. A series of road tests under different environments have been carried out for the NEO modules. These tests allow to measure the position accuracy delivered by the GNSS receivers. The accuracy, calculated as the offset to the real position, is showed in percentiles for 2D and 3D coordinates.

3.6.2.1 Rural areas with good GNSS visibility

Figure 6 shows such position accuracy on a radar plot for the NEO-M8Q/N, NEO-M8M and NEO-M8J. The scenario consists mostly of rural areas with relatively good GNSS visibility and strong signals, reporting CN0 values of about 42 dBHz for some signals. The road test results show that crystal-based NEO-M8M and NEO-M8J have very similar position accuracy compared to the TCXO-based NEO-M8Q/N modules in rural areas.

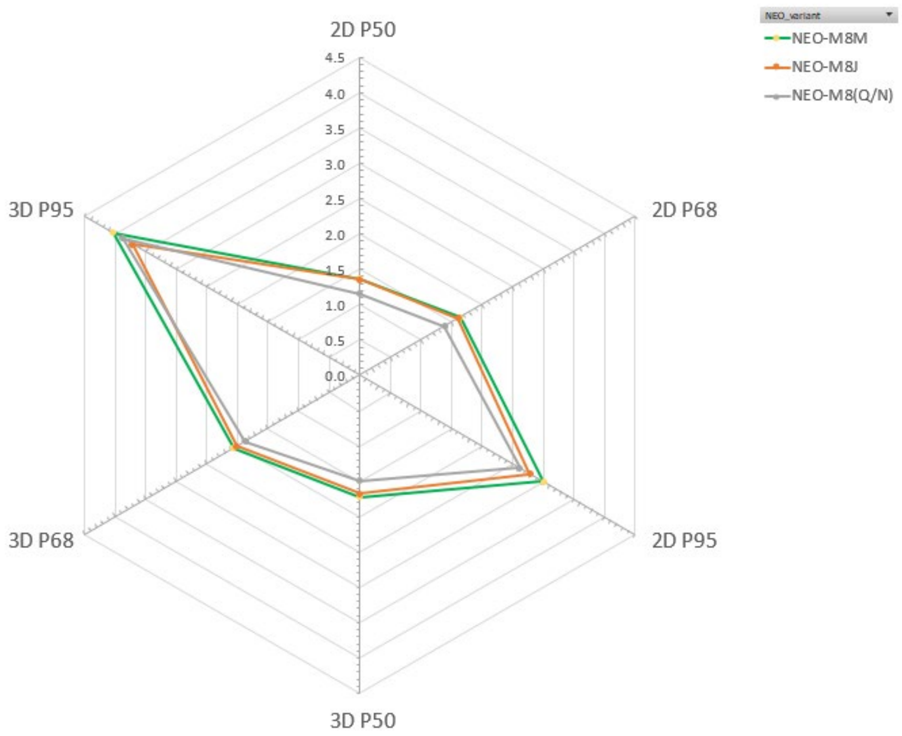


Figure 6: Position error in meters for NEO-M8Q/N and NEO-M8M in percentiles. Rural areas with good signal reception conditions.

The following four images (Figure 7, Figure 8, Figure 9, and Figure 10) show the real track (in green) and the position calculated by the NEO-M8Q/N (in grey), NEO-M8J (in orange) and NEO-M8M (in blue). It is obvious that the navigation output of all TCXO and crystal-based NEO variants are very similar.

Figure 7: NEO-M8(Q/N) in red, NEO-M8M in blue, NEO-M8J in yellow, and reference position tracks (in green) in rural areas while changing heading of motion

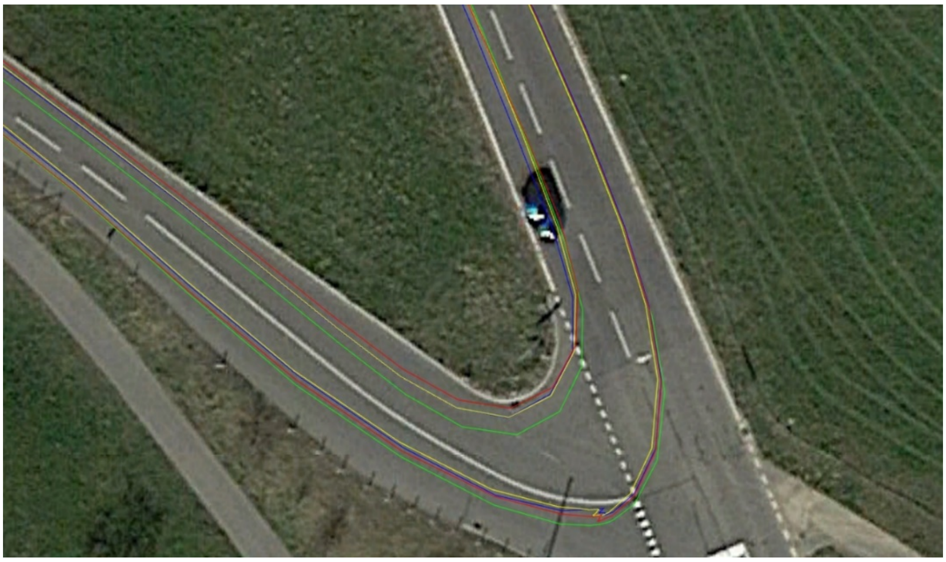


Figure 8: NEO-M8(Q/N), NEO-M8M, NEO-M8J, and reference position tracks in curves. Same color pattern as in Figure 7.

Figure 9: NEO-M8(Q/N), NEO-M8M, NEO-M8J, and reference position tracks in rural areas in a roundabout. Same color pattern as in Figure 7.

Figure 10: NEO-M8(Q/N), NEO-M8M, and reference position tracks in rural areas. Similar position deviation seen in all variants. Same color pattern as in Figure 7.

3.6.2.2 Urban canyon with weak signal levels and multipath

In urban canyon (weak signal level) scenarios, the position accuracy is also similar between NEO-M8Q/N, NEO-M8M, and NEO-M8J, independent of the signal power levels.

The Figure 11 below shows the same position accuracy percentiles for an urban canyon environment. The signal levels remain low, with a median C/No values of 36.5 dBHz.

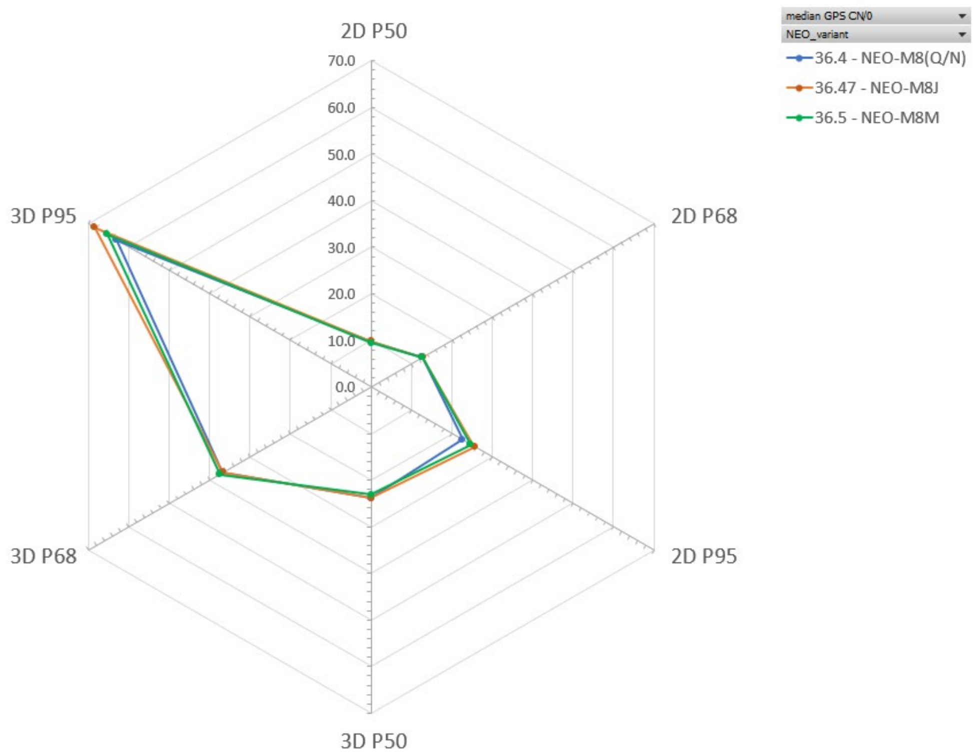


Figure 11: Position error in meters for NEO-M8Q/N and NEO-M8M in percentiles. Urban canyon scenario.

Note that although the position errors are very big for all NEO modules, such performance is expected for all standard precision GNSS receivers under such a challenging environment. The real track (in green) followed is shown in Figure 12 below.

Figure 12: Scenario used for urban canyon to compare performance between NEO-M8(Q/N) and NEO-M8M

Again, we see similarities on how all NEO-M8 modules calculate the position. Refer to the tracks of NEO-M8Q/N (in red) and NEO-M8M (in blue) compared to the real track (in green) in the Figure 13 below.

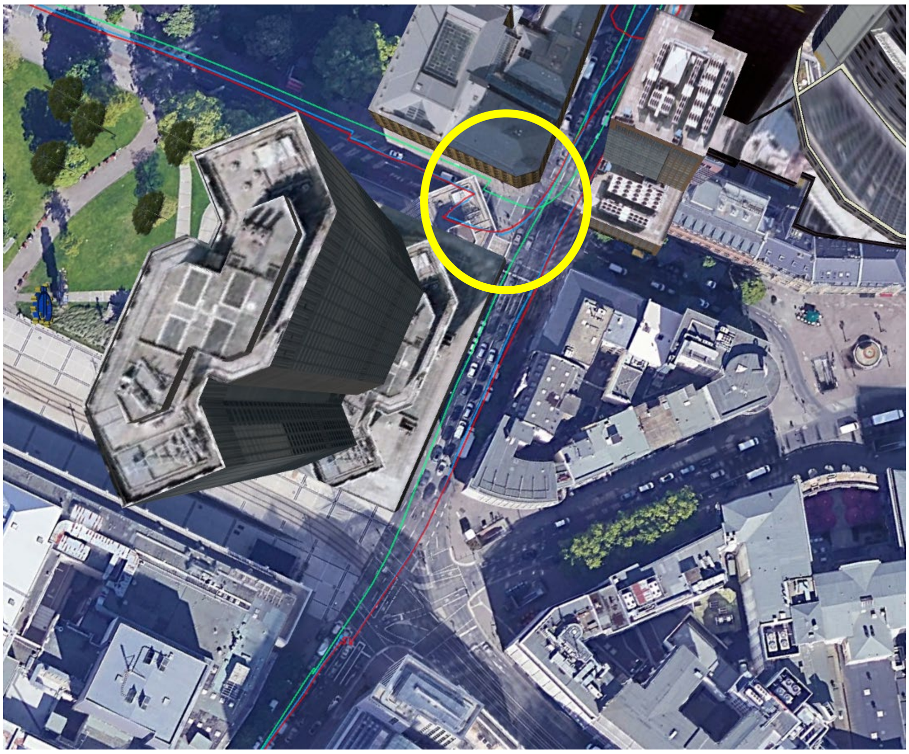


Figure 13: Similarities in the position output between NEO-M8Q/N and NEO-M8M under weak signals and in a multipath environment

3.6.2.3 Highway road and good signal levels

Finally, a highway scenario has been used in the road test. In this case, the receiver calculates a position where conditions change rapidly due to the car speed. Figure 14 captures a part of the drive and gives a good representation of the test conditions.

The higher speed is more challenging for GNSS receivers due to the tracking loops. The highway scenario means the tracking is more difficult. Thus, the degradation of the signal levels has a larger influence on the position accuracy. The active antennas will significantly help the GNSS receiver performance here.

Figure 14: Part of the "Highway" scenario used and track of the receivers

The presence of medium distance tunnels along the road does not have a significant impact on the NEO-M8Q/N module, all TCXO and crystal-based modules recovering the position quickly after the tunnel exit. See the real track in green, the NEO-M8Q/N in red, NEO-M8J in yellow, and NEO-M8M in blue in the figure below.

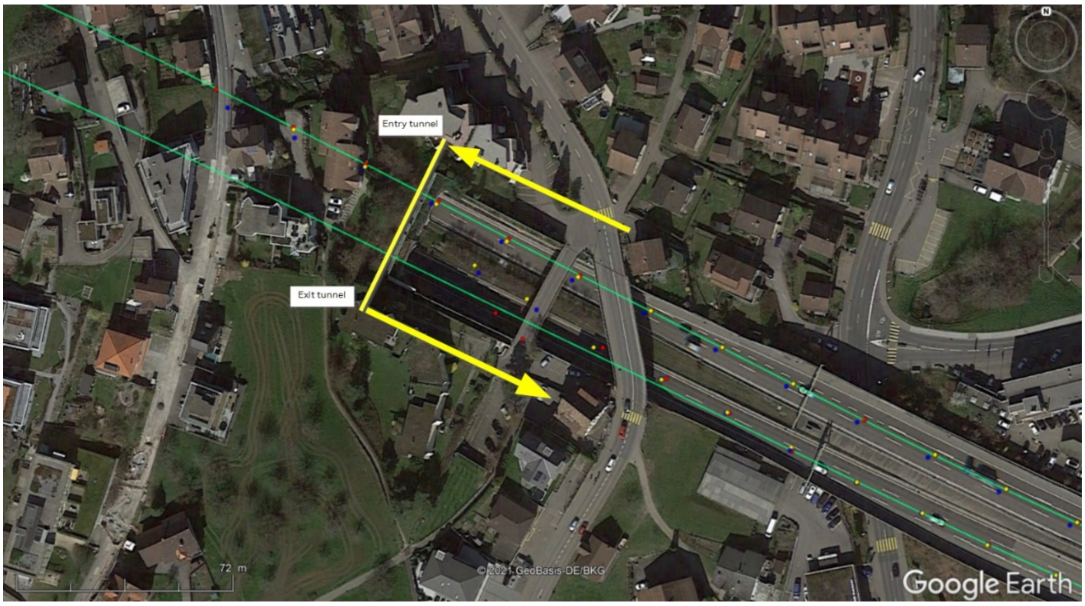


Figure 15: Quick position recovery after tunnel exit with low GNSS visibility

Each colored dot in the figure represents the navigation solution for each epoch. The crystal variants, blue for NEO-M8M and yellow for NEO-M8J in Figure 15, show the capability to calculate position straight after exiting a tunnel at high speed and with a very low GNSS visibility.

Figure 16 shows the position error in meters for NEO-M8Q/N, NEO-M8M and NEO-M8J in percentiles in a highway test scenario. The highway results demonstrate once again that the crystal-based NEO modules have very similar position accuracy compared to the TCXO-based NEO-M8Q/N modules.

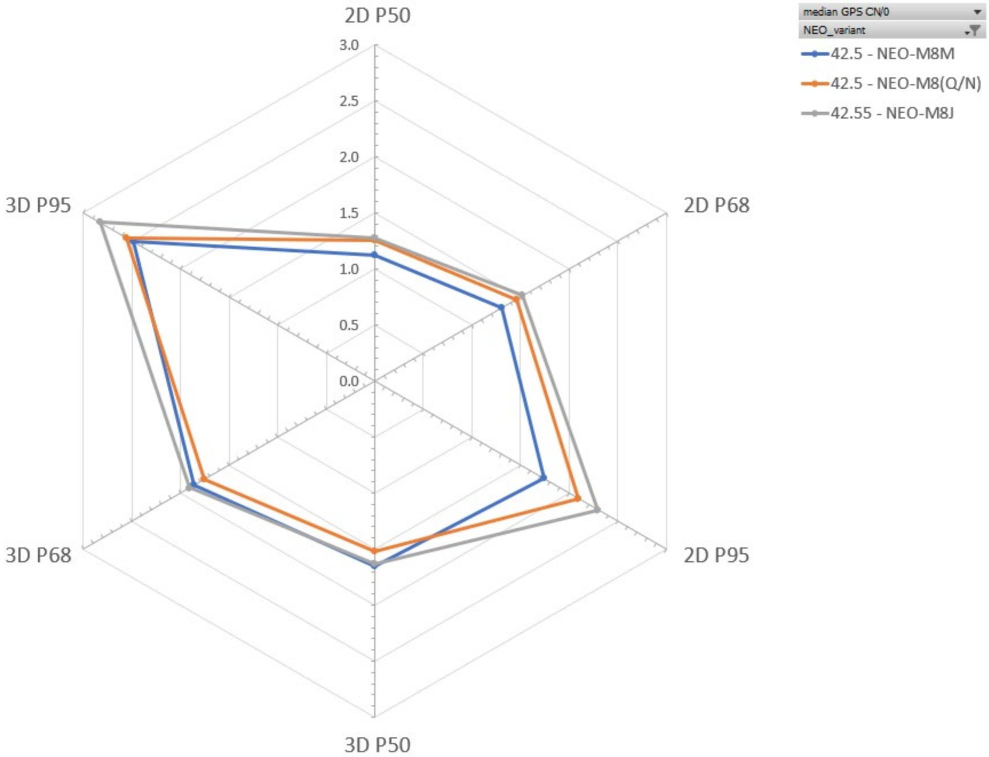


Figure 16: Position error in meters for NEO-M8Q/N, NEO-M8J, and NEO-M8M in percentiles in a highway scenario

4 NEO-8Q

This section provides details on the migration from TCXO-based NEO-8Q to crystal-based NEO-M8(M/J) module. The differences between those three modules are listed in Table 4.

4.1 NEO-8Q vs. NEO-M8(M/J)

The table below summarizes the specifications to be considered during the migration.

Field	Parameter	NEO-8Q	NEO-M8M	NEO-M8J
HW	**Oscillator**	TCXO	Crystal	Crystal
	Interface config.	Same	Same	Same
	Pinout	Same	Same [12]	Same
	Flash memory	None	None	Yes
	GNSS	Single (GPS or GLO)	Multi-GNSS (up to 3 concurrent GNSS)	Multi-GNSS (up to 3 concurrent GNSS)
RF design	**Front-end**	Integrated SAW + LNA in place	With passive antenna, an external LNA is **recommended.** SAW filter is optional.	Integrated SAW [13] + LNA in place
	Out-of-band immunity	Good	Poor	Good
Temp.	**Storage temp. °(C)**	Max +85	Max +105	Max +85

[12] LNA_EN pin is reserved in NEO-M8M. In case this pin is used to switch on/off external LNA, see section 3.5.
[13] The NEO-M8J integrates an SAW filter with better out-of-band immunity than in NEO-8Q.

	Thermal isolation [14]	Recommended	Highly recommended	Highly recommended
Power Req.	**Supply (Vcc & Vio) (V)**	[2.7 - 3.6]	[1.65 - 3.6]	[2.7 - 3.6]
	Supply current (mA)	22	21	29
	SW backup current (mA)	Same	Same	Same
	HW backup current (mA)	Same	Same	Same
Sensitivity	**Dynamic Tracking (dBm)**	-166	-164	-164
	TTFF (sec) [15]	29	26	26
SW	**Firmware**	ROM SPG 3.01	ROM SPG 3.01	Flash FW SPG 3.05 [16]
	Max navigation rate (Hz)	18	10 [17]	5

Table 4: NEO-8Q to NEO-M8(M/J) migration comparison (in default mode, NEO-8Q: GPS, QZSS and SBAS; NEO-M8M/J: GPS & GLONASS including QZSS, SBAS)

☞ When migrating to crystal-based NEO-M8(M/J) module, make sure the receiver is not operated in Galileo-only mode. Crystal variants are not suitable for Galileo-only operation due to worse performance (TTFF, sensitivity) as documented in the NEO-M8 Data sheet [3].

4.2 Power requirements

Although both modules have similar current draw, the power consumption of the TCXO and LNA present in the NEO-8Q is compensated with the multi-constellation feature of the NEO-M8(M/J), which requires a higher CPU load. Refer to NEO-8Q Data sheet [4] for detailed current consumption-related information.

4.3 Sensitivity and position accuracy

All parameters related to sensitivity, time-to-first-fix, and tracking sensitivity will improve when migrating from the single-GNSS NEO-8Q to multi-GNSS NEO-M8(M/J). This is because NEO-M8(M/J) supports the simultaneous use of up to three GNSS constellations.

With GPS and GLO enabled by default, NEO-M8(M/J) fixes position three seconds faster on average under the same good signal reception, which is achievable in all those designs with multi-GNSS active antenna or external LNA present. For the same reason, other parameters like position accuracy will also be improved when migrating to multi-GNSS NEO-M8(M/J) solution.

For more information about the performance of the NEO-M8M and NEO-M8J, see section 3.6.

5 NEO-7N

This section provides details on the migration from TCXO-based NEO-7N to crystal-based NEO-7M, and the upgrade possibility to the crystal-based NEO-M8(M/J).

☞ Before making the decision to migrate from NEO-7N to the crystal-based NEO-7M version, u-blox recommends considering an upgrade to the newer generation NEO-M8(M/J). See section 5.7.

[14] Mainly for applications where the GNSS module is under thermal activity on the board.
[15] Cold and hot start under good GNSS visibility and using power levels of -130 dBm.
[16] For details refer to GNSS FW SPG3.05 Release notes [8].
[17] With single GNSS constellation, the navigation rate can achieve 18 Hz.

Table 5 shows comparison between NEO-7N and NEO-7M. Table 6 in section 5.8 shows comparison of NEO-7N to NEO-M8(M/J).

5.1 NEO-7(N/M)

Field	Parameter	NEO-7N	NEO-7M
HW	**Oscillator**	TCXO	Crystal
	Flash memory	Yes	None
	Interface config.	Same	Same
	Pinout	Same	Same
RF design	**Front-end**	Integrated SAW + LNA	With passive antenna, an external LNA is recommended, SAW filter is optional.
	Out-of-band immunity	Good	Poor
Temp.	**Storage temp. °(C)**	Max +85	Max +105
	Thermal isolation [18]	Recommended	Highly recommended
Power Req.	**Supply (Vcc & Vio) (V)**	[2.7 - 3.6]	[1.65 - 3.6]
	Supply current (mA)	26	17
	SW backup current (mA)	0.035	0.02
	HW backup current (mA)	Same	Same
Sensitivity	**Dynamic Tracking (dBm)**	Same	Same
	TTFF (sec) [19]	30	32
	Cold start sensitivity (dBm)	-140	-139
	Hot start sensitivity (dBm)	-156	-155
SW	**Firmware**	Flash FW 1.00	ROM 1.00
	External LNA control	Yes	No

Table 5: NEO-7N to NEO-7M migration comparison (default mode: GPS, QZSS and SBAS)

5.2 Power requirements

In terms of power consumption, the migration to the crystal version NEO-7M saves LNA power, flash memory, and the crystal oscillator also needs less power. More information is available in the NEO-7 Data sheet [5].

5.3 RF front-end

The TCXO-based NEO-7N has an SAW filter and an LNA in the RF-front, which are not present in the crystal-based NEO-7M module.

The SAW filter placed as the first element in the RF path acts as GNSS pass-band filter, attenuating other signals coupled into the RF signal. Such filtering is important on applications exposed to strong jamming environments or that incorporate cellular antennas. The SAW filter is followed by an LNA[20], which will amplify the filtered signal and forward it to the chip. As mentioned in section 2.1, an LNA is recommended in applications using a passive antenna.

During the migration process, it is important to determine if the device will be under strong RF interference sources. In that case, the SAW filter in the front might significantly improve the performance. Note that if these filters are not ideal, a small attenuation at the GNSS bands will be present. Refer to NEO-7 Hardware Integration Manual [2] for a selection of suitable filters and LNAs for out-of-band immunity mitigation.

[18] Mainly for applications where the GNSS module is under thermal activity on the board.
[19] Cold and hot start under good GNSS visibility and using power levels of -130 dBm.
[20] The importance of the LNA for a crystal module has been explained in a previous section.

5.4 Internal flash memory

The NEO-7N has a 16-Mbit SQI flash memory that is not present in the NEO-7M. This might have an important impact on the device operation if not present when migrating to the NEO-7M.

The programmable memory allows to save the configuration permanently, update the FW, data logging, and store long-term orbit data for a faster position fix. The lack of the memory can be resolved if:

1. The data is saved at the host side and sent to the receiver at each startup, like AssistNow Offline.
2. The host sends the configuration messages to the receiver at each startup.
3. An external backup battery or external supply at V_BCKP pin keeps the BBR (battery-backed RAM) alive.

In addition, flash also provides the upgradability of the FW. However, considering the maturity of the ROM 1.00 FW in the NEO-7M and that no further FW releases are expected, migrating from flash-based NEO-7N to ROM-based NEO-7M does not cause any extra concern.

5.5 ANT_ON feature

The NEO-7N can shut down an optional external LNA using the ANT_ON signal to optimize power consumption. Note that this feature is not present in the NEO-7M.

In case this feature is wanted, it can be implemented on the host processor side.

5.6 Performance

5.6.1 Startup sensitivity and TTFF

Crystal-based GNSS receivers are characterized as having a longer time to synchronize with GNSS signals. The effect is more visible when the signals are weak and the GNSS visibility is poor.

This is reflected on the tracking sensitivity and time-to-first-fix for cold, warm, and hot starts, and can be seen in Table 5, or more in detail in the NEO-7 Data sheet [5].

As has been seen in other u-blox 7 modules, the sensitivity degradation occurs in case of weak GNSS signals. With signals above 40 dBHz the performance, in this case time-to-first-fix, is very similar. This can easily be achieved using an active antenna, or an external LNA.

As an example, Figure 12 shows a plot using data from MAX-7 modules, one with a TCXO (orange line), and the other with a crystal (blue line). Similar behavior is expected from NEO-7N and NEO-7M modules.

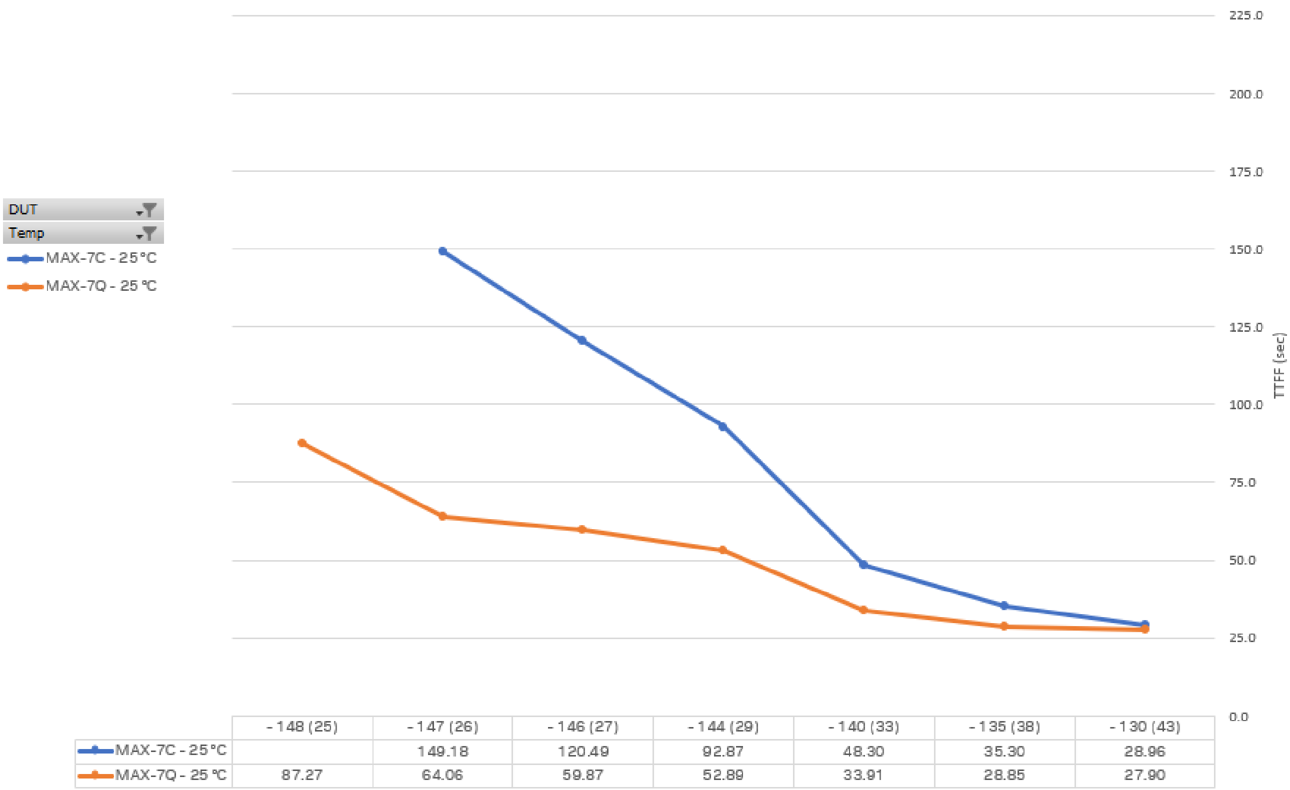


Figure 17: TTFF vs. signal power in dBm and its equivalent in C/N0 inside parentheses for MAX-7Q and MAX-7C during cold starts (default mode: GPS & GLONASS including QZSS, SBAS)

☞ In case of migration to the crystal variant NEO-7M, u-blox recommends an upgrade to the new generation NEO-M8(M/J), which will significantly improve the performance, thanks to the multi-GNSS benefits, which can compensate for the performance degradation of the crystal under weak GNSS signals. See section 3.6 Performance for details.

5.7 Upgrading NEO-7N to NEO-M8(M/J)

The upgrade will allow the customer to benefit from the improved SPG 3.01 firmware (better tracking sensitivity) compared to ROM 1.00 used in the NEO-7 modules. In addition, the NEO-M8(M/J) is a multi-GNSS receiver. Thanks to the higher number of available satellites, it significantly improves the TTFFs, sensitivity, and performance, especially in dynamic and difficult environments.

It is highly advisable that customers consider a migration design review with the u-blox technical support team to ensure the compatibility of key functionalities. Refer to u-blox 7, u-blox 8, and u-blox M8 software migration guide [6] and GNSS FW3.01 Release notes [7] for more details about the software-related migration.

5.8 NEO-7N vs. NEO-M8(M/J)

Field	Parameter	NEO-7N	NEO-M8M	NEO-M8J
HW	**Oscillator**	TCXO	Crystal	Crystal
	Flash memory	Yes	None	Yes
	Interface config.	Same	Same	Same
	Pinout	Same	Same [21]	Same
	GNSS	Single (GPS or GLO)	Multi-GNSS (up to 3 concurrent GNSS)	Multi-GNSS (up to 3 concurrent GNSS)

[21] ANT_ON pin is reserved in NEO-M8M. In case this pin is used to switch on/off external LNA, see section 5.7.2.

RF design	**Front-end**	Integrated SAW + LNA	With passive antenna, an external LNA is **recommended.** SAW filter is optional.	Integrated SAW[22] + LNA
	Out-of-band immunity	Good	Poor	Good
Temp.	**Storage temp. °(C)**	Max +85	Max +105	Max +85
	Thermal isolation[23]	Recommended	Highly recommended	Highly recommended
Power req.	**Supply (Vcc & Vio) (V)**	[2.7 - 3.6]	[1.65 - 3.6]	[2.7 - 3.6]
	Supply current (mA)	26	21	29
	SW backup current (mA)	Same	Same	Same
	HW backup current (mA)	Same	Same	Same
Sensitivity	**Dynamic Tracking (dBm)**	-158	-164	-164
	TTFF (sec)[24]	30	26	26
	Cold starts sensitivity (dBm)	-140	-148	-148
	Hot starts sensitivity (dBm)	-156	-157	-157
SW	**Firmware**	Flash FW 1.00	ROM SPG 3.01	Flash FW SPG 3.05[25]
	External LNA control	Yes	No	Yes

Table 6: NEO-7N to NEO-M8(M/J) migration comparison (default configuration)

☞ When migrating to crystal-based NEO-M8(M/J) module, make sure the receiver is not operated in Galileo-only mode. Crystal variants are not suitable for Galileo-only operation due to worse performance (TTFF, sensitivity) as documented in the NEO-M8 Data sheet [3].

5.8.1 ANT_ON feature

The NEO-7N can shut down an optional external LNA using the ANT_ON pin to optimize power consumption in power save mode.

Note that this feature is not present in the NEO-M8M and the pin is marked as reserved. In case this feature is wanted, it must be implemented on the host processor side, requiring some redesign.

This ANT_ON option is available in the NEO-M8J as LNA_EN pin.

5.8.2 Internal flash memory

The NEO-7N has an internal flash memory that is not present in the NEO-M8M, and it is needed in certain applications. Refer to the section 5.4 for more details.

The NEO-M8J has internal flash memory.

5.8.3 Performance

5.8.3.1 Startup sensitivity and TTFF

Because of the higher number of tracking satellites in multi-GNSS NEO-M8(M/J), TTFF values with strong signals at room temperature are even lower than the TCXO-based single-GNSS NEO-7M.

This is clearly visible in the values shown in Table 6, with a remarkable difference of up to 8 dB for cold starts, and a four-second improvement for time-to-first-fix.

[22] The NEO-M8J integrates an SAW filter with better out-of-band immunity than in NEO-7N.
[23] Mainly for applications where the GNSS module is under thermal activity on the board.
[24] Cold and hot start under good GNSS visibility and using power levels of -130 dBm.
[25] For details refer to GNSS FW SPG3.05 Release notes [8]

For more information about the performance of the NEO-M8M and NEO-M8J, see section 3.6.

☞ Note that a multi-GNSS antenna is required for NEO-M8M/NEO-M8J design.

6 Conclusion

Large and well-designed passive patch antennas, external LNA or active antennas can work perfectly well with u-blox crystal-based NEO receivers despite the minimal performance differences between the crystal and the TCXO variants. The results obtained from our tests clearly show that the NEO-M8M solution is good for applications where operation with a weak signal is not necessary.

Consequently, for customers with active antennas or an external LNA in their current designs, there should be no issue when switching from TCXO-based NEO-M8Q/N and NEO-8Q to crystal-based NEO-M8M.

This also applies to the migration from TCXO-based NEO-7N to crystal-based NEO-7M or NEO-M8M. In case of an upgrade to M8, the test results even show that the multi-GNSS operation in NEO-M8 crystal modules will bring better performance. Refer to section 5 for detailed comparison of the different options.

The NEO-M8J, on the other hand, is the perfect migration solution for applications without an active antenna or an external LNA. The crystal-based NEO-M8J (with flash, SAW+LNA) fills the gap between the TCXO-based NEO-M8N/M8Q and the existing cost-efficient, crystal-based NEO-M8M solution, thus making the TCXO-to-crystal migration much easier. The NEO-M8J can directly replace the NEO-M8N without modifications in the application.

Contact u-blox technical support team for guidelines for finding the best suitable crystal-based solution for your TCXO-based NEO designs.

Related documentation

[1] NEO-8Q, NEO-M8 Hardware integration manual, UBX-15029985
[2] NEO-7 Hardware integration manual, UBX-13003704
[3] NEO-M8 Data sheet, UBX-15031086
[4] NEO-8Q Data sheet, UBX-15031913
[5] NEO-7 Data sheet, UBX-13003830
[6] u-blox 7 to u-blox 8 and u-blox M8 software migration guide, UBX-15031124
[7] GNSS FW3.01 Release notes, UBX-16000319
[8] GNSS FW SPG3.05 Release notes, UBX-21015240

☞ For product change notifications and regular updates of u-blox documentation, register on our website, www.u-blox.com.

Revision history

Revision	Date	Name	Comments
R01	29-Jan-2021	imar	Initial draft
R02	01-Mar-2021	imar	Added NEO-M8J
R03	28-Jun-2021	imar	Added NEO-M8J current consumption numbers in section 3.1 and 3.2, updated NEO-M8J FW version (SPG 3.05), added NEO-M8J cold start TTFF figures in section 3.6.1, updated road test data with NEO-M8J results.

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