Kvaser Air Bridge System Integration Guide

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1 About this document

This document provides guidance for integrating the Kvaser Air Bridge devices in different system environments. It consists of an introduction to the Kvaser Air Bridge family, followed by integration guidelines that aim to give you a complete understanding of how to adapt to the Kvaser Air Bridge variants to maximize its performance within your application. Use Section 4, Design-in guidelines, on Page 11 when designing-in Kvaser Air Bridge to a new application.

Besides the variant specific User's Guide, two complementary documents are available:

- Kvaser Air Bridge Installation Guide
- Kvaser Air Bridge Management Interface Description

The User's Guide describes the hardware's properties and provides instructions on commissioning and configuration of operational parameters and, if applicable, on firmware upgrade.

The Kvaser Air Bridge Installation Guide provides installation advice for end-users who use Kvaser Air Bridge and want to optimize radio performance and reach.

The Kvaser Air Bridge System Integration Guide provides design-in advice for system integrators who use Kvaser Air Bridge as a system component and want to make the most of its data bridging capability, not least in scenarios where multiple Kvaser Air Bridge devices are to be employed.

The Kvaser Air Bridge Management Interface Description provides information about the Kvaser Air Bridge's Management Interface, an application-level request/response protocol that enables a user application to access the control- and monitoring services of a Kvaser Air Bridge device. The Kvaser Air Bridge Management Interface Description is not applicable for Kvaser Air Bridge Light HS variants.

2 Introduction

The Kvaser Air Bridge product family consists of the following product variants:

Device	Product Number	Firmware version
Kvaser Air Bridge Light HS	73-30130-00808-3	2.4.0
Kvaser Air Bridge Light HS (FCC)	73-30130-01008-6	2.4.0
Kvaser Air Bridge Light HS M12	73-30130-01141-0	2.4.0
Kvaser Air Bridge Light HS M12 (FCC)	73-30130-01148-9	2.4.0
Kvaser Air Bridge M12	73-30130-01494-7	2.4.0

Table 1: Kvaser Air Bridge devices and their EAN numbers.

Whilst the four Kvaser Air Bridge Light HS variants are purchased in sets of two devices which have been statically paired with each other, the last variant, Kvaser Air Bridge M12, is a 'one-to-any' device which can be paired freely with any other 'one-to-any' device. It is therefore purchased as a single device to allow for any number of devices to be acquired.

The (00808-3 and 01141-0) Kvaser Air Bridge Light HS variants are approved for the European Union, while the (01008-6 and 01148-9) Kvaser Air Bridge Light HS (FCC) variants are optimized for the US. They both share the same functionality but have different radio transmitting schemes due to regulatory differences. The (01494-7) Kvaser Air Bridge M12 variant is approved for both the European Union and the US.

Note: all Kvaser Air Bridge devices marked with an FCC ID are approved for use in the US.

Over the years, the Kvaser Air Bridge Light HS variants have been subject to gradual improvement realized by a series of firmware releases. However, the differences in features. functionality and performance characteristics related to firmware release are only briefly mentioned in this document and instead, reference is given to version 1.0 of this document for more detailed descriptions of older releases. Refer to the Kvaser Air Bridge user's guides for information on firmware upgrade and on how to find out which firmware resides on each individual device.

To aid readability, the name Kvaser Air Bridge is hereinafter used to refer to the Kvaser Air Bridge product in general. The name Kvaser Air Bridge Light is used to refer to any of the four Kvaser Air Bridge Light HS variants and the name Kvaser Air Bridge 'one-to-any' is used to refer to the more advanced Kvaser Air Bridge M12 variant.

2.1 What is Kvaser Air Bridge?

The Kvaser Air Bridge devices contain radio transceiver that can be used to establish a CAN system bridge for the transfer of messages wirelessly between two CAN bus segments.

All Kvaser Air Bridge devices operate in the so-called 2.4 GHz ISM band. This is an unlicensed frequency band open for applications in industry, science and medical sectors. Equipment using this frequency band includes mobile phones, computers, wireless access points, car alarms, garage door openers, remote-controlled machinery etc.

All Kvaser Air Bridge devices include radio transceivers with power amplifiers that provide the maximum allowed transmit power, ensuring a robust connection and maximizing the communication distance potential. The omni-directional antennas enable transmission and reception in any direction. Provided that the Kvaser Air Bridge devices are mounted favorably, 360-degree coverage can be obtained.

Refer to the Kvaser Air Bridge Installation Guide for more guidance.

2.2 Kvaser Air Bridge Light vs Kvaser Air Bridge ’one-to-any’

Kvaser Air Bridge Light consists of two statically paired ’one-to-any’ devices that enable a simple and straight forward establishment of a CAN system bridge between the two CAN segments to which the Kvaser Air Bridge Light devices are connected. The two paired Kvaser Air Bridge Light devices will automatically establish a connection between CAN bus segments without any user interaction.

Kvaser Air Bridge ’one-to-any’ is a multi-role device that can be commissioned as either Primary device or Secondary device. A Kvaser Air Bridge ’one-to-any’ Primary device can be paired with any Kvaser Air Bridge ’one-to-any’ Secondary device. The pairing feature provides the automatic discovery of all available Kvaser Air Bridge ’one-to-any’ Secondary devices within reach of the radio signals. This information is transferred to the user application at the Kvaser Air Bridge ’one-to-any’ Primary device, which can thereby select freely which Kvaser Air Bridge ’one-to-any’ Secondary device to pair with.

Pairing with a preferred Kvaser Air Bridge ’one-to-any’ Secondary device is also possible without it being within radio reach. The actual pairing procedure is then completed once the devices are within reach of each other. As long as two Kvaser Air Bridge ’one-to-any’ devices have been paired with each other, a connection will automatically be established between the CAN bus segments to which they are connected, provided that the two Kvaser Air Bridge ’one-to-any’ devices are within reach of each other. No other interaction is required.

The pairing of the Kvaser Air Bridge ’one-to-any’ devices is carried out through the exchange of special messages exchanged over the CAN bus interface, the so called Management Interface which is described in a separate document. The Management Interface also embodies all the features related to commissioning of the Kvaser Air Bridge ’one-to-any’ devices, but does not apply to the Kvaser Air Bridge Light.

To commission the Kvaser Air Bridge devices, a special Kvaser Air Bridge Utility CLI is available. The Kvaser Air Bridge Utility CLI facilitates the commissioning of the devices and the configuration of some operational settings; their roles (Primary device or Secondary device), pairing codes, and CAN bus bit rate. Kvaser Air Bridge Light does not need to be commissioned but the Kvaser Air Bridge Utility CLI can be used to change the CAN bus bit rate.

Commissioning is the procedure employed by the user before putting Kvaser Air Bridge devices into service. The commissioning can be performed using the Kvaser Air Bridge Utility tool or by exchanging special messages between the Kvaser Air Bridge and a user appliction over the connected CAN bus segment. The latter is only possible for Kvaser Air Bridge 'one-to-any' devices.

Refer to the Kvaser Air Bridge Management Interface Description for guidance related to commissioning and management of the devices.

Refer to the Kvaser Air Bridge user's guides for guidance related to the Kvaser Air Bridge Utility CLI.

3 Kvaser Air Bridge Operation

3.1 Spectrum availability and co-existence

As the 2.4 GHz ISM band is made available for many different radio technologies, it is subject to various rules that aim to establish co-existence in areas that are densely populated with transmitters and receivers using the same frequency band. Such rules include spreading the radio energy across the frequency band and preventing simultaneous transmission by radio equipment in close vicinity. It's important to note that although the 2.4 GHz ISM band serves to promote co-existence between radio transceivers, there may be situations where degraded radio communication is experienced.

The Kvaser Air Bridge employs special features to make it a robust radio link, most notably a frequency hopping approach that uses around 40 frequencies. Besides frequency hopping, a special 'Listen Before Transmit' mechanism invokes a 'Clear Channel Assessment' before every transmission. If another radio is located nearby the Kvaser Air Bridge device and transmits on the designated frequency, then the data will not be transmitted on that frequency but rather on the next available frequency.

3.2 Radio link establishment

A radio link is automatically established between two Kvaser Air Bridge devices when their radio signals can be mutually received, and provided that they have been paired. For a pair of Kvaser Air Bridge Light devices this is always the case. For Kvaser Air Bridge 'one-to-any' devices, this happens directly following the pairing procedure, provided that the Kvaser Air Bridge 'one-to-any' Secondary device is not already paired and connected to another Kvaser Air Bridge 'one-to-any' Primary device.

If the radio reception is poor due to a week signal level, interference or a combination of the two, the radio link is still maintained even though there is no exchange of data. However, after a certain time, the Kvaser Air Bridge 'one-to-any' Secondary device will enter a mode in which it will try to re-establish the radio link without transmitting. This will go on indefinitely. In such a situation, and after some time with poor reception, the Kvaser Air Bridge 'one-to-any' Secondary device will become available for pairing with any Kvaser Air Bridge 'one-to-any' Primary device, just like a Kvaser Air Bridge 'one-to-any' device that has not been paired.

A Kvaser Air Bridge 'one-to-any' Secondary device that is paired with another Kvaser Air Bridge 'one-to-any' Primary device cannot be paired with another Kvaser Air Bridge 'one-to-any' Primary device.

> Pairing is the process of logically associating a Kvaser Air Bridge 'one-to-any' Primary device with a Kvaser Air Bridge 'one-to-any' Secondary device. The pairing involves special procedures for automatic discovery of nearby Kvaser Air Bridge Secondary devices and measures to prevent unwanted pairing with Kvaser Air Bridge devices belonging to other users.

Refer to the Kvaser Air Bridge Management Interface Description for guidance related to pairing.

3.3 Transmission and reception of messages over radio

As with any radio-based system, a careful and sound installation approach will ensure optimal communication. This concerns the surrounding structures, in addition to other emitters that may disturb the radio communication. Near-by devices may also be using the 2.4 GHz ISM band, or there may be apparatus unintentionally emitting energy in this band.

The Kvaser Air Bridge devices rely on a Time Division Multiple Access scheme based on intervals of 2.4 ms length, so called 'time slots' in which a Kvaser Air Bridge device is either transmitting or receiving. Depending on which is the case, the underlying timing is different, which is why two types of slots are used, i.e. either a transmit slot or a receive slot.

For Kvaser Air Bridge 'one-to-any' devices there is also a third type of slot to accommodate for the pairing feature. This is a random access slot in which Kvaser Air Bridge 'one-to-any' Secondary devices are allowed to respond to a pairing request from a Kvaser Air Bridge 'one-to-any' Primary device. These operate in a random fashion that reduces the risk of collision, which would be the case if two or more Kvaser Air Bridge 'one-to-any' Secondary devices respond at the same time. For Kvaser Air Bridge Light devices, the random access slot does not apply.

Once a radio link is established, the two Kvaser Air Bridge devices involved take turns in transferring messages. The transfer is based on a Time Division Duplex protocol with a fixed cycle length of 4.8 ms of which each Kvaser Air Bridge device is allocated 50%. The 2.4 ms time slot in each direction provides adequate time for the transmitter and receiver to reliably synchronize and transfer the messages at short latency. For each transmit interval, a new frequency is selected according to a frequency hopping scheme that ensures equal use of the available frequencies. The Kvaser Air Bridge can avoid transmitting on frequencies presently used by other nearby radio devices.

In scenarios involving multiple Kvaser Air Bridge devices, it is recommended that all devices use the same firmware version to optimize performance. Please contact Kvaser support for more information.

3.4 CAN connection

The Kvaser Air Bridge provides a simple approach that preserves many CAN bus features, and it can automatically adapt to the CAN bus bit rates thanks to an autobaud feature.

As the transfer of messages over radio always introduces a certain latency, it cannot support arbitration between the CAN bus segments. This means that a message sent on one CAN bus will be subject to a second arbitration on the other CAN bus after being transferred over the radio link. On the other hand, all messages received on the Kvaser Air Bridge's own CAN bus interface will be directly acknowledged according to the CAN standard, i.e. even before they are transmitted to its paired Kvaser Air Bridge device.

Autobaud is the process of automatically selecting the correct bus parameters for communication on the connected CAN bus based on received CAN traffic.

4 Design-in guidelines

To highlight the benefits of the Kvaser Air Bridge as a system component, the following 'design-in guidelines' serve to help a system integrator to optimize performance for different use cases. The Kvaser Air Bridge system exhibits characteristics that make it especially suitable for:

- Remote control systems
- Supervision systems
- Provisioning of data
- Bus monitoring and logging
- Diagnostics

Data communication is essentially about capacity and timing characteristics. It is important to understand the possibilities and limitations of radio-based data links and networks and to relate these to the overall system requirements and use case. Just as important is a good understanding of the CAN protocol, particularly arbitration and acknowledge mechanisms, error frame handling and bus load impact.

Critical systems may need special precautions to be taken to ensure a robust and safe system design and development programs may require special procedures to be strictly followed. The recommendations below provide guidance on how to make the most out of the Kvaser Air Bridge.

4.1 Rule 1. Appropriate commissioning of the devices

Prior to the employment if Kvaser Air Bridge devices into a system, they need to be commissioned by configuration of some important operational parameters. A special tool, the Kvaser Air Bridge Utility CLI, is available to support this commissioning.

For the Kvaser Air Bridge 'one-to-any', the following could be configured by using the Kvaser Air Bridge Utility CLI:

Role (Primary or Secondary device) Every Kvaser Air Bridge 'one-to-any' device is delivered as a Secondary device. Therefore, a certain number of the acquired devices need to be configured as Primary devices, depending on the use case and systems in which they are to be employed.

Pairing codes The pairing process should be protected from interference from other systems using Kvaser Air Bridge 'one-to-any', whether own systems or systems operated by another company. If no pairing codes are defined, the default codes are used. Generally, all Kvaser Air Bridge 'one-to-any' devices that are intended to be part of a system should have an identical set of pairing codes.

Bit rate If the bit rates used by a system are known, then it is an advantage to configure the bit rates of the Kvaser Air Bridge ’one-to-any’ devices, thereby disabling the autobaud feature which adds to the set-up time and which requires activity on the CAN bus segments to be bridged.

A list of available commands and parameters for the Kvaser Air Bridge Utility CLI is available in its user dialogue. Refer to the Kvaser Air Bridge user’s guides.

The Kvaser Air Bridge Light is plug and play, meaning that it is statically paired and that it cannot be unpaired or paired with another device. For the Kvaser Air Bridge Light, only the bit rate and transmit power are configurable.

Note: The Kvaser Air Bridge ’one-to-any’ devices can also be configured from an application software implementing commands on tthe Management Interface. The Management Interface is not available for Kvaser Air Bridge Light.

4.2 Rule 2. Enable correct start-up

If the Kvaser Air Bridge devices are paired, which is always the case for Kvaser Air Bridge Light, then as soon as both Kvaser Air Bridge devices have been powered up, they start the radio link establishment procedure. Once the radio link between the Kvaser Air Bridge devices has been established, they will be ready to transfer messages between their respective CAN bus segments.

If the Kvaser Air Bridge devices have been powered up before they have been paired, then they will be ready to transfer messages directly after the pairing activity.

Note: The transfer of messages between the two CAN bus segments require either that the correct bit rates are chosen or that the autobaud feature has successfully chosen the bit rates, see Section 4.6, Rule 6. Make certain that the automatic bitrate detection time can be handled, on Page 14.

4.3 Rule 3. Determine the conditions for the Kvaser Air Bridge implementation

Fundamental to a Kvaser Air Bridge implementation, as for any radio solution, is that the system application is well understood. Regardless of its capacity or "bandwidth", a radio-based data link is subject to latency that must not be neglected. Also, a radio-based data link can generally not obtain the signal robustness exhibited by a cable without sacrificing the performance with respect to latency.

Kvaser Air Bridge is optimized for control link applications and hence provides excellent performance in these aspects. Yet, there are considerations to be made:

- Is the application sensitive to latency or jitter and if so, can it be modified for more resilience?
- Does the application require a maximum round-trip delay, i.e. the time it takes for a message to be wirelessly transferred from one CAN bus segment to the other until a response has been transferred back to the originator. Can the application be modified in this respect?
- Is the desired throughput high? If this is the case, will it be possible to reduce the bus load by e.g. adapting the update rate for some of the messages? Even if the capacity of the Kvaser Air Bridge is sufficient, reducing the load is generally beneficial in many ways.
- Are there messages that do not need to be transferred from one CAN bus segment to the other. If this is the case, the CAN filters provided by Kvaser Air Bridge ’one-to-any’ can be employed.
- Does the system generate bursts of messages and if so, at what intensity? Can the traffic generated be evened out over time?

4.4 Rule 4. Choose appropriate pairing and unpairing methods

Depending on the use case, one out of two pairing methods can be used for the Kvaser Air Bridge ’one-to-any’:

For use cases in which the application cannot predict which device to pair with, the discovery pairing method can be used. This pairing method consists of a discovery phase followed by an optional selection of the most appropriate device out of those devices that have been discovered. During the discovery phase, the Kvaser Air Bridge ’one-to-any’ devices can transfer "User Status" and "Custom Data" from each Secondary Kvaser Air Bridge ’one-to-any’ device to the Kvaser Air Bridge ’one-to-any’ Primary device and from the Kvaser Air Bridge ’one-to-any’ Primary device to Kvaser Air Bridge ’one-to-any’ Secondary devices. These are small amounts of data that enable an application developer to introduce user controlled pairing protection mechanisms, innovative context-based features, automated priority solutions, resource handover mechanisms etc.

For use cases in which the device to be paired with is known in advance, the targeted pairing method can be used. This implies that the device can be selected even before the devices have been powered up or while they were out of reach from each other.

By default, the Kvaser Air Bridge Light is plug and play, meaning that it is statically paired and that it cannot be paired with another device.

More information can be found in the Kvaser Air Bridge Management Interface Description.

4.5 Rule 5. Limit the bus loads

The transfer capacity of the Kvaser Air Bridge corresponds to an average CAN bus bit rate of 250 kbit/s in each direction, which implies twice this CAN bus bit rate if the transfer between CAN bus segments were equal in both directions. The message transfer capacity increases with shorter payload (DLC) in the transferred messages.

Note: For Kvaser Air Bridge Light variants with a firmware release older than that listed in Table 1 on Page 5, the capactiy is somewhat lower. The capacity would increase by 25-30% if the firmware were upgraded.

The message transfer capacity in each direction of the Kvaser Air Bridge defines the maximum number of messages generated by the nodes on each CAN bus segment.

It is an advantage if the number of messages can be limited to some extent to account for possible causes of interference, such as occupied frequencies. An adequate bus load could for example be 80% in relation to the Kvaser Air Bridge transfer capacity given in Section 5.2, Transfer capacity, on Page 20.

Different approaches may apply for different use cases. For some applications, a flow control mechanism may be suitable. For others, the message rate needs to be defined for every CAN node.

4.6 Rule 6. Make certain that the automatic bitrate detection time can be handled

By default, all Kvaser Air Bridge devices are configured for automatic bit rate selection, autobaud, for which one of the four bit rate pre-sets below can be automatically selected.

- 1 Mbit/s
- 500 kbit/s
- 250 kbit/s
- 125 kbit/s

The bit rates on the two bridged CAN bus segments can be chosen independently from each other thanks to an automatic bit rate conversion built into the Kvaser Air Bridge.

The autobaud feature requires that there is activity on at least one of CAN bus segments. In the case when there is activity on one CAN bus segment only, then the detected bit rate will be used on both paired Kvaser Air Bridge devices.

The Autobaud selection requires that messages are transmitted onto either of the CAN bus segments by another CAN node. If no supported CAN bus bit rate has been detected by a Kvaser Air Bridge device within 15 seconds after the radio link has been established, it will select the same bit rate as the other device. If neither Kvaser Air Bridge device has detected a supported network bit rate within 15 seconds after power up, the Autobaud Detection will be governed by whichever Kvaser Air Bridge device detects CAN bus bit rate first. There is no limit to the time that the Kvaser Air Bridge devices will wait for a message on their CAN bus segments.

Should the radio link for some reason be interrupted, it will automatically be re-established without the need for renewed Autobaud Detection.

By using the Kvaser Air Bridge Utility CLI, either one of the four bit rate pre-sets or autobaud can be configured. For the Kvaser Air Bridge 'one-to-any' it can also be controlled from an application software implementing commands on the Management Interface.

Should the autobaud feature create problems for the user application, either because 15 seconds is too long for the application or that the other units on one of the CAN bus segments do not start transmit until the Kvaser Air Bridge device does so, then the Kvaser Air Bridge provides four pre-defined bit rate pre-sets that do not rely on automatic bit rate detection for it to work, see Section 4.7 Rule 7. Optionally select a bit rate pre-set for the CAN bus segments.

4.7 Rule 7. Optionally select a bit rate pre-set for the CAN bus segments

The Kvaser Air Bridge provides pre-defined CAN configurations corresponding to the four bit rate pre-sets below. The nominal sampling point for these CAN configurations is between 87% and 89%. For more information about the CAN configuration, see Section 6.1, Custom CAN Configuration, on Page 22.

It is always possible to configure the Kvaser Air Bridge devices to Autobaud. Note that each of the Kvaser Air Bridge devices can be configured independently to one of the above bit rates.

A high bit rate gives an advantage concerning latency related to arbitration and message transfer on the CAN buses. Also, a high bit rate means that the Kvaser Air Bridge radio packets are used more efficiently. Generally, a bus load of less than 50% is often recommended.

Note: For Kvaser Air Bridge Light firmware releases older than those listed in Table 1 on Page 5, only the autobaud feature is available.

Should another bit rate than the four bit rate pre-sets or another CAN configuration (with different bus characteristics) be desired, the Kvaser Air Bridge 'one-to-any' supports a fully configurable custom CAN configuration.

4.8 Rule 8. Optionally specify custom CAN configuration

For applications where the bit rate pre-sets are inappropriate the Kvaser Air Bridge 'one-to-any' supports an application specific custom CAN configuration, enabling the setting of the following parameters:

- CAN bus bit rate (up to 1 Mbit/s)
- Bit segment 1
- Bit segment 2
- Sync Jump Width
- Silent mode

The CAN bus bit rate value is the desired bit rate whereas the Bit segment values are firm values that determine the sample point in the bit period. The Kvaser Air Bridge calculates the best possible match based on these values and on its internal clock.

The Sync Jump Width is a value that determines the tolerances within which the Kvaser Air Bridge is allowed to synchronize to the transmissions on the CAN bus. This is often a critical parameter which has an important relationship to the Bit segments.

Note: For the custom CAN configuration to be activated, it must not only be defined but also selected as a sixth custom alternative bit rate pre-set (besides the four pre-sets and autobaud). This sixth alternative is only available for the Kvaser Air Bridge 'one-to-any'. If the custom CAN configuration is selected without it being defined, this selection will be replaced by the 1 Mbit/s alternative.

For more information, see Section 6.1, Custom CAN Configuration, on Page 22.

4.9 Rule 9. Limit transients bus load (message bursts)

The maximum transient bus load generated on each of the CAN bus segments within a short period and transferred to the other CAN bus segment may need to be limited to prevent an overflow in the transmit buffer, as this would lead to messages in the buffer being discarded. If a flow control mechanism is implemented, it should set a limit to the transient bus load (or message bursts) that can be generated on each of the two bridged CAN bus segments.

The bus load or number of messages over a certain time period could then be controlled to avoid unnecessary data loss. The possible transient bus load transferred from one CAN bus segment to the other is limited by the message transfer capacity of the Kvaser Air Bridge and its transmit buffer. For Kvaser Air Bridge Light variants with firmware release older than what is stated in Table 1 on Page 5, the capacity is somewhat lower.

The maximum transient bus load transferred from one CAN bus segment to the other is illustrated for three CAN bus bit rates in the following diagram:

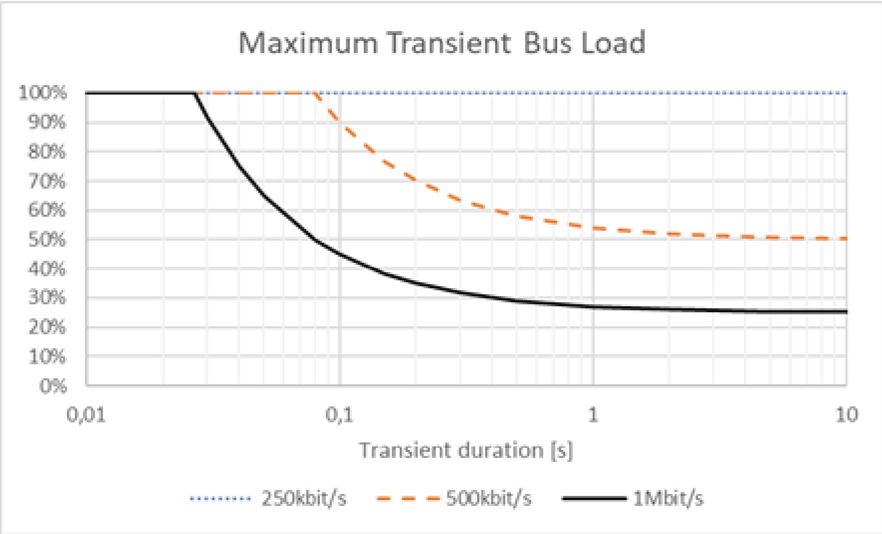

Figure 1: Maximum transient bus load transferred from one CAN bus segment to the other.

The diagram shows that for a bit rate of 500 kbit/s, the maximum long term bus load for the Kvaser Air Bridge generated on one of the CAN bus segments is 50%, the Kvaser Air Bridge is capable of handling twice that (100%) if the duration of the transient bus load is shorter than 80 ms and provided that an average bus of 50% is maintained over time.

For a bit rate of 1 Mbit/s the maximum long term bus load generated on one of the CAN bus segments is 25%. The Kvaser Air Bridge can transfer a bus load of 100% if the duration is shorter than around 25 ms and provided that an average bus of 25% is maintained over time.

For a bit rate of 250 kbit/s or for lower bit rates, the Kvaser Air Bridge supports 100% bus load generated on one of the CAN bus segments.

Note: For Kvaser Air Bridge firmware releases older than the one listed in Table 1 on Page 5, the maximum long term bus load depends slightly on the CAN identifier length. For 11-bit ID the long-term bus load supported is 80% of the above, whereas for 29-bit ID it is 70% of the above. For transient bus load for Kvaser Air Bridge Light, refer to a revision of the respective User's Guide issued before that listed in Table 1 on Page 5.

It must be noted that the total bus load on each of the CAN bus segments consists of the bus load generated on both bridged CAN bus segments, and that there is a limit to this total bus load which is determined by the CAN bus segments with the lowest bit rate.

Note also that it is recommended that a margin of around 20% be kept depending on the application and on the radio signal environment in relation to the communication distance.

For more information, please contact Kvaser support.

4.10 Rule 10. Apply CAN filters if relevant

Kvaser Air Bridge 'one-to-any' supports CAN filters that can be used to reduce the load on the wireless connection. Up to four filters can be defined consisting of filter identifier and filter mask.

For more information, see Section 6.2, CAN Filtering, on Page 24.

4.11 Rule 11. Make sure latency can be handled

Although the average transfer latency introduced by the Kvaser Air Bridge is normally 4.8 ms, there is a slight probability that a packet cannot be correctly transferred and will thereby be retransmitted. At most, a message in the Kvaser Air Bridge will be retransmitted twice before being discarded. Because retransmissions are expected to occur seldomly, the average transfer latency introduced by Kvaser Air Bridge would normally be around 5 ms.

Additional latency may result from retransmissions due to interference by nearby emitters and from weak radio signal caused by long distance or poor propagation conditions.

The latency will increase for each retransmission required but will return quickly to normal when the interference disappears or when propagation conditions improve.

Please contact Kvaser support for more detailed information on latency.

4.12 Rule 12. Ensure resilience to packet loss

Applications must consider the probability of lost messages over the Kvaser Air Bridge, as with any radio-based data link. Depending on the type of information conveyed in a message, the message loss should be handled in different ways.

Applications may, for example need to incorporate a transport protocol to ensure that the transmitted messages are received correctly. Such a protocol must consider the round-trip latency, which besides latency introduced by the Kvaser Air Bridge system, also includes application response time, transfer latency related to the message lengths and any other kind of latency that may occur in conjunction with arbitration on the local CAN buses.

In case an application employs a watch dog functionality using so called 'heartbeat' messages and such a message is lost, there is a risk of a false alarm issued by a corresponding supervisory mechanism. Therefore, the heartbeat interval may need to be shortened so that the alarm timeout period encompasses at least two intervals. Alternatively, the timeout period can be lengthened if the supervision response time is acceptable.

4.13 Rule 13. Supervise the connection and device status

The Kvaser Air Bridge 'one-to-any' provides the means to supervise the link and device by simple means of status information services that can be subscribed via the Management Interface:

- Link status
- Device status

Link status is a boolean that reflects the continuity of received radio packets. The criteria for evaluation of the continuity can be altered by specifying the number of consecutive radio packets that must be correctly received in order to conclude that the link is UP and how many consecutive lost radio packets that are required to conclude that the link is DOWN.

Device status is a watch dog function which continuously reports that the Kvaser Air Bridge is operating as normal.

For more information, refer to Kvaser Air Bridge Management Interface Description.

5 Message transfer considerations

The recommendations relate to aspects discussed specifically below.

5.1 Degradation aspects

As described earlier, interference or low signal level may result in a disturbed radio signal but not necessarily loss of messages. That is because a transmitting Kvaser Air Bridge device will automatically retransmit packets that haven't been acknowledged by the receiving Kvaser Air Bridge device. Retransmission and related buffering will lead to an increase in latency and as there is a limit to how many times a certain packet may be retransmitted, there may be situations in which messages are eventually lost because of interference. The loss of messages in such a situation would be detected as part of a transport protocol implemented on a higher level.

5.2 Transfer capacity

There is also a limit to how many messages can be transferred between two Kvaser Air Bridge devices, its transfer capacity, but this is also limited by the bit rate of the connected CAN bus segments. Assume for example that one of the CAN bus segments has a lower bit rate than the other, then it is the lowest bit rate that limits the overall throughput. Both CAN bus segments must, however, be able to handle the total number of messages transferred within the CAN system, i.e. all the messages received and transmitted by the Kvaser Air Bridge on each CAN bus segment.

The transfer capacity in each direction of the Kvaser Air Bridge is 250 kbit/s on average for the Kvaser Air Bridge 'one-to-any'. For Kvaser Air Bridge Light HS variants with firmware that is older than that listed in Table 1 on Page 5, the average capactiy depends on the length of the CAN identifier field (11 bits or 29 bits) where the average transfer capacity is 200 kbit/s for 11 bits CAN identifier field and 175 kbit/s for 29 bits CAN identifier field. The capacity also depends on the payload length of the CAN frames. For Kvaser Air Bridge Light variants with firmware that is older than that listed in Table 1 on Page 5, refer to an earlier revision of the respective User's Guide.

Please contact Kvaser support for more detailed information on transfer capacity.

5.3 Retransmission

As explained above, interference or low signal level may result in some messages experiencing more latency than others because of retransmission and related buffering. The order of the messages is retained and the maximum number of retransmissions would normally limit the latency for each individual message. However, nearby emitters very close to the transmitter may occupy some frequencies occasionally, preventing transmission or retransmission from taking place on those frequencies. Each Kvaser Air Bridge device therefore contains a transmit buffer.

5.4 Transmit buffering

Depending on the number of messages on the CAN bus in relation to the throughput between Kvaser Air Bridge devices, there is also the possibility of overflow of the internal transmit buffer in the Kvaser Air Bridge device. In such a situation, messages in the transmit buffer will be discarded. It is always the oldest message that is transmitted or discarded first.

5.5 Receive buffering

Similar considerations are also relevant for the Kvaser Air Bridge device that is receiving information. A Kvaser Air Bridge device includes a receive buffer from which messages are transferred from the local CAN bus. The messages in the receive buffer could be discarded only in the case of a very high bus load.

5.6 Latency

The latency of transferred messages introduced by Kvaser Air Bridge is normally 4.8 ms $\pm$ 2.4 ms. This partly relates to message processing but more importantly to the 4.8 ms transmission cycle which accounts for 4.8 ms $\pm$ 2.4 ms, depending on the moment in time when the message is sent on the CAN bus. If the radio transfer is subject to interference, this may result in an additional 4.8 ms or 9.6 ms caused by retransmission. If a Kvaser Air Bridge device is prevented from transmitting (by other signals from nearby radios) there will be additional latency. Likewise, if the transmitting Kvaser Air Bridge device does not receive an acknowledgement from the other Kvaser Air Bridge device, it will retransmit the respective message before proceeding with transmission of the following messages.

As for all CAN bus systems, arbitration may cause additional latency depending on bit rate on the CAN buses and lower bit rate means a longer time to transfer messages over the CAN bus.

6 Appendices

In this section you will find technical information about the Kvaser Air Bridge.

6.1 Custom CAN Configuration

All Kvaser Air Bridge devices support CAN 2.0A (Standard CAN) and CAN 2.0B (Extended CAN or High-speed CAN). Generally, the Kvaser Air Bridge provides four alternative bit rate pre-sets:

- 1 Mbit/s
- 500 kbit/s
- 250 kbit/s
- 125 kbit/s

As an alternative to these standard bit rate pre-sets, the Kvaser Air Bridge M12 ('one-to-any') supports a Custom CAN Configuration with configurable CAN bus timing for precise control of bit rate, sampling point and resynchronization. A user can thereby obtain the wanted bit rate and appropriate timing parameters to control the sampling position in the bit period and the maximum allowed synchronization adjustment, Sync Jump Width. In addition, the user can set the CAN interface into "silent" mode. The configuration involves the following parameters:

Configurable parameter	Description
Bit rate	Bit rate (desired bit rate in bits/s, maximum 1000)
Tseg1	Bit time segment 1 (in time quanta, between 1 and 16)[1]
Tseg2	Bit time segment 2 (in time quanta, between 1 and 8)
Sync	Sync segment (always one time quantum)
SJW	Sync Jump Width (in time quanta, between 1 and 4)[2]
Silent	Silent mode (boolean value)

Table 2: Configurable parameters.

The bit timing is presented in the below figure:

The Kvaser Air Bridge calculates the best match to the desired bit rate based on its internal clock, 36 MHz and the bit segment values, based on which it selects the closest possible pre-scaler. There may hence be a slight difference between the desired bit rate and the resulting one. However, by careful consideration given to the bit segment values, it may be possible to exactly match the desired bit rate. It depends on the selection of pre-scaler to the clock frequency.

If the ratio between 36 MHz and the desired bit rate is an integer, a perfect match may be possible, but it depends on how this ratio can be factorized. If one of the

[1] Bit time segment 1 must be equal or greater than Bit time segment 2.
[2] Sync Jump Width must be equal or smaller than Bit time segment 2.

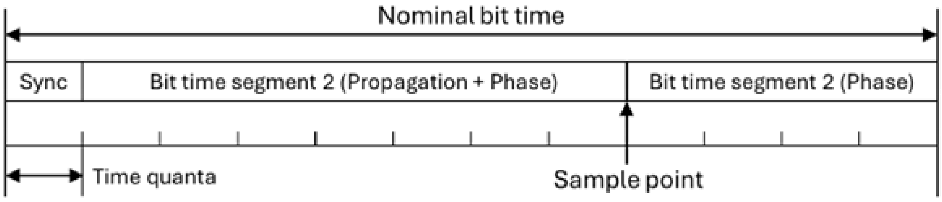

Figure 2: Bit timing.

factors is between 3 and 25 (the minimum and maximum number of time quanta (tq) in a bit) then a perfect match is possible. Assume for example that a bit rate of 160 kHz is desired, then the ratio is 225 (36000/160) and the factorization of 225 is $5 \times 5 \times 3 \times 3$. This yields five alternative numbers of time quanta in a bit: 3, 5, 9, 15 and 25 corresponding to the pre-scaler values: 75, 45, 25, 15 and 9.

What is more important, however, is the sample point, which is governed by the ratio between bit time segments, and the maximum phase shift in the resynchronization. Often, a sampling point at around 75% of the bit is recommended. If the number of time quanta were 15, then Tseg1 would be 10 and Tseg2 would be 4 yielding a sample point of 73%.

The Sync Jump Width (SJW) may be critical but depends highly on CAN configuration for the other nodes on the bus. A SJW value of 2 would enable a phase shift of up to 13% in either direction.

The values and performance of the standard bit rate configurations is given below:

	125	**250**	**500**	**1000**
Sync [tq] (fixed)	1	1	1	1
Tseg1 [tq]	13	6	6	7
Tseg2 [tq]	2	1	1	1
SJW [tq]	1	1	1	1
Bit length [tq]	16	8	8	9
Sampling point [%]	88%	88%	88%	89%

Table 3: Values and performance of the standard bit rate configurations.

In addition to the above configurations, the CAN interface can be put into a silent mode in which the CAN hardware in the Kvaser Air Bridge is prevented from transmitting onto the CAN bus.

For more information, refer to the following documents on Kvaser's web site:

- The CAN Bus Protocol Tutorial
- CAN Bus Timing Calculator

6.2 CAN Filtering

The Kvaser Air Bridge M12 (EAN:73-30130-01494-7) 'one-to-any' supports the employment of CAN Filters.

CAN filters can be used to significantly reduce the number of messages transferred wirelessly between the two CAN bus segments to which the Kvaser Air Bridge devices are connected.

There may be several reasons to reduce the load on the wireless link between the Kvaser Air Bridge devices:

- The CPU resources may be scarce on a node connected to one of the CAN bus segments.
- The Bit rate chosen on the two CAN bus segments may be such that the number of messages transferred from one segment to the other must be reduced.
- There is only interest in transferring a limited number of CAN identifiers between the CAN bus segments.
- Messages sent unnecessarily over the Kvaser Air Bridge needs to be blocked to make certain that important messages in the other direction are not delayed by arbitration.

Generally, it is always an advantage if filters can be used, to reduce the utilization of a wireless link. If there is interference to the radio signal, then one or more messages may need to be retransmitted causing not only increased latency for those particular messages but also increased load on the wireless link. Normally this is not a problem for Kvaser Air Bridge thanks to its unique diversity scheme. But for situations with considerable interference from nearby radio transmitters, the high load may eventually result in messages being dropped. Also, as Kvaser Air Bridge is designed to provide a low latency connection, there is a maximum number of retransmissions to the message transfer.

From a utilization perspective, there is essentially no relationship between the wireless link's two directions. However, as the retransmission scheme depends on acknowledgements, a lost radio transmission will cause retransmission, regardless of whether the transmission that was to be acknowledged was lost or not. Therefore, it is advantageous to reduce the load on both directions of the wireless link.

Kvaser Air Bridge 'one-to-any' therefore provides the means to apply different filters in both directions, meaning that filters can be individually configured per device. This applies to CAN 2.0A (Standard CAN) and CAN 2.0B (Extended CAN or High-speed CAN). The filters thereby distinguish between 11-bit ID (Standard CAN) and 29-bit ID (Extended CAN).

A filter consists of a filter ID and a filter mask of the same length as the filter ID. The filter mask defines which bit positions are employed in the filtering. This way, either individual CAN IDs or certain ranges of CAN IDs can be filtered. All configured filters remain after a power cycle and they are employed simultaneously:

Example:

	Hex	**Binary**
Filter ID	456	100 0101 0110
Filter mask	72F	111 **0**11**0** 1111

Table 4: Example of filter ID and mask.

In this case, every bit position marked 1 in the filter mask needs to be matched to the filter ID while there are two bit-positions for which CAN identifiers do not need to be matched to the filter ID. This will result in letting through four CAN identifiers (the unmatched bit positions are marked in bold):

	Hex	**Binary**
CAN ID passed	446	100 **0**10**0** 0110
CAN ID passed	456	100 **0**10**1** 0110
CAN ID passed	4C6	100 **1**10**0** 0110
CAN ID passed	4D6	100 **1**10**1** 0110

Table 5: CAN IDs allowed by the example filter

Whether this results in unwanted CAN identifiers being transferred wirelessly or not, is of course a question about whether the CAN identifiers are used in the CAN bus system or not.

Hence, a careful selection of CAN identifiers and CAN filters in the CAN bus system may prove to give an advantage when it comes to maximizing the robustness of the wireless link and minimizing the message transfer latency for the Kvaser Air Bridge 'one-to-any'.

Note: Filters are only available for the Kvaser Air Bridge 'one-to-any'.

The configuration of CAN filters is available with the Kvaser Air Bridge Utility CLI and also via the Kvaser Air Bridge Management Interface. For more information, refer to the Kvaser Air Bridge User's Guide and the Kvaser Air Bridge Management Interface Description.

7 Document Revision History

Version history for document IN_98227_air_bridge_system_integration_guide:

Revision	Date	Changes
1.0	2020-11-09	Initial version.
2.0	2024-02-01	Updated the system integration guide.
2.1	2024-03-15	Updated Kvaser logo.
3.0	2024-09-06	Updated the system integration guide.