Kvaser Air Bridge System Integration Guide

https://www.kvaser.com

Printed Wednesday 22nd May, 2024

(This page is intentionally left blank.)

Contents

1 About this document

This document provides guidance for integrating the Kvaser Air Bridge units in different system environments. It consists of an introduction to Kvaser Air Bridge, followed by integration guidelines that aim to give you a complete understanding of how to adapt to the Kvaser Air Bridge to maximize its performance within your application. Use Section 3, Design-in guidelines, on Page 9 when designing-in Kvaser Air Bridge to a new application.

Three complementary documents are available:

- Kvaser Air Bridge Installation Guide
- Kvaser Air Bridge System Integration Guide
- Kvaser Air Bridge Management Interface description

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. The Kvaser Air Bridge Management Interface is an application-level request/response protocol that enables a user application to access the control- and monitoring services of a Kvaser Air Bridge device.

2 Introduction

The Kvaser Air Bridge product family consists of one standard variant and four light variants:

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

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

The (00808-3 and 01141-0) Kvaser Air Bridge Light HS is approved for the European Union, while (01008-6 and 01148-9) Kvaser Air Bridge Light HS (FCC) is 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 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.

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 M12 is used to refer to the specific product and NOT the product in general.

2.1 What is Kvaser Air Bridge?

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

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.

2.2 How does Kvaser Air Bridge work?

The Kvaser Air Bridge can be used in many situations to bridge two CAN systems. Kvaser Air Bridge is a multi-role device that can be commissioned as either Master unit or Slave unit. A Master unit can be paired with any Slave unit through the exchange of special messages exchanged over the CAN bus interface. The pairing feature provides automatic discovery of all available Slave units within reach of the radio signals. This information is transferred to the user application at the Master unit, which can thereby select freely which Slave unit to pair with. Pairing with a preferred Slave unit is also possible without it being within radio reach.

A connection will automatically be established between CAN systems with two paired Kvaser Air Bridge units. No other interaction is required.

All Kvaser Air Bridge units 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 favourably, 360-degree coverage can be obtained. See the Kvaser Air Bridge Installation Guide for more guidance.

Commissioning is the procedure employed by the user before putting Kvaser Air Bridge units 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. Commissioning involves allocation of roles to the devices (Master unit or Slave unit) and the configuration of keys to establish a user specific private domain of Kvaser Air Bridge devices, to prevent unwanted pairing with Kvaser Air Bridge devices belonging to other users.

See the Kvaser Air Bridge Management Interface Description for guidance related to commissioning and pairing.

2.3 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 of each other. 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 unit and transmits on the designated frequency, then the data will not be transmitted on that frequency but rather on the next available frequency.

2.4 Radio link establishment

If a Kvaser Air Bridge Master unit and Kvaser Air Bridge Slave unit have been paired, a radio link is automatically established between them when their radio signals are within reach of each other.

If the radio signals are lost, the radio link is still maintained even though there is no exchange of data and after a certain time, the radio link is logically disconnected until the radio signals can be detected again. If a Slave unit becomes logically disconnected from its paired Master unit, it becomes available to be paired to any Master unit.

A special un-pairing feature is also available to disassociate a Slave unit from its paired Master unit. After an unpairing, the Slave unit becomes available to be paired to any Master unit.

Pairing is the process of logically associating a Kvaser Air Bridge Master unit with a Kvaser Air Bridge Slave unit. The pairing involves special procedures for automatic discovery of nearby Kvaser Air Bridge Slave units and measures to prevent unwanted pairing with Kvaser Air Bridge devices belonging to other users.

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

2.5 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 units take turns in transferring messages over the 2.4 GHz ISM band. 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 unit is allocated 50%. The 2.4 ms transmit interval 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 has the ability to avoid transmitting on frequencies presently used by other nearby radio devices.

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

2.6 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 systems. 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 unit.

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

3 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, in particular 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 below recommendations provide guidance of how to make the most out of the Kvaser Air Bridge.

Rule 1. Enable correct start-up

As soon as both Kvaser Air Bridge units have been powered up and paired, they start the radio link establishment procedure. Once the radio link between the Kvaser Air Bridge units has been established, they will be ready to transfer messages between their respective CAN systems, i.e. provided that Autobaud Detection, if enabled, has completed successfully.

By default, the Kvaser Air Bridge Light HS, is plug and play meaning that it is pre-paired and that it cannot be unpaired or paired with another device. Also, the autobaud feature is always enabled for Kvaser Air Bridge Light HS.

For Kvaser Air Bridge M12, it is possible to disable the autobaud feature and instead configure a pre-set bit rate which results in a much shorter link set-up time.

Rule 2. Provide conditions for the autobaud feature to determine the bit rates

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

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

Rule 3. Limit the bus loads

The transfer capacity of the Kvaser Air Bridge corresponds to an average CAN bus bit rate of approximately 200 kbit/s for Kvaser Air Bridge Light HS and 250 kbit/s for Kvaser Air Bridge M12 in each direction or to twice this CAN bus bit rate if the transfer between CAN systems were equal in both directions. The capacity increases with shorter payload (DLC) in the transferred messages.

The transfer capacity of the Kvaser Air Bridge defines the maximum number of messages generated by the nodes on each CAN system.

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 4.2, Transfer capacity, on Page 14.

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.

Rule 4. Choose appropriate bit rates on the CAN bus systems

The bit rates on the connected CAN buses do not need to be the same. The Kvaser Air Bridge does not have a default bit rate but enables each unit to independently select any of the following CAN bus bit rates:

- 125 kbit/s
- 250 kbit/s
- 500 kbit/s
- 1000 kbit/s

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 recommended.

The built-in autobaud feature enables the Kvaser Air Bridge to automatically adapt to the selected bus bit rate, but each of the Kvaser Air Bridge M12 devices can be configured independently to one of the above bit rates.

Rule 5. Limit transients bus load (message bursts)

The maximum transient bus load generated on each of the CAN systems within a short period and transferred to the other CAN system may need to be limited in order 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 side of the Kvaser Air Bridge M12.

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 side of the Kvaser Air Bridge M12 to the other is limited by the transfer capacity of the Kvaser Air Bridge M12 and its transmit buffer. The maximum transient bus load transferred from one side of the Kvaser Air Bridge M12 to the other is illustrated for three CAN bus bit rates in the following diagram:

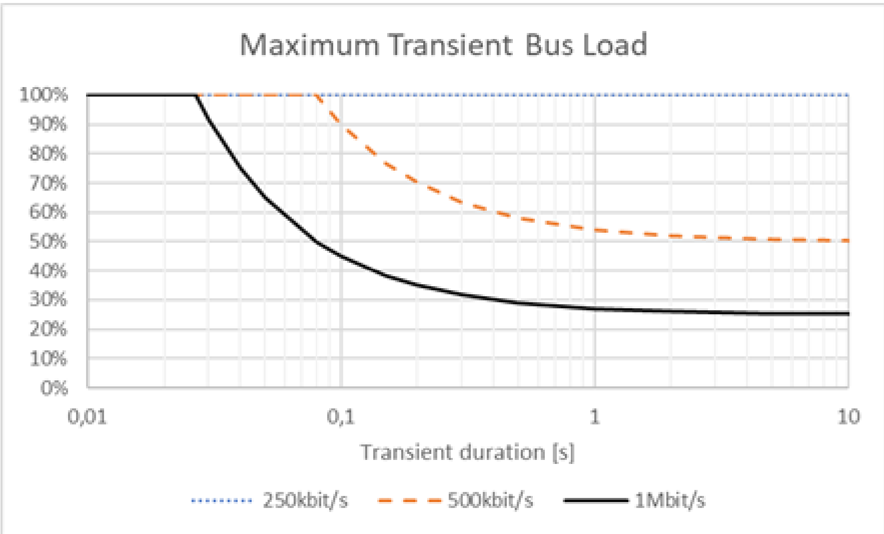

Figure 1: Maximum transient bus load transferred from one side of the Kvaser Air Bridge M12 to the other.

The diagram shows that for a bit rate of 500 kbit/s, the maximum long term bus load for the Kvaser Air Bridge M12 generated on one of the CAN bus segments is 50% and that the Kvaser Air Bridge M12 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 M12 is capable of transferring 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 bus load generated on one of the CAN bus segments can be 100% at all times for Kvaser Air Bridge M12.

The the maximum long term bus load for Kvaser Air Bridge Light HS depends slightly on the CAN-ID length. For 11-bit ID it is 80% of that of Kvaser Air Bridge M12 whereas for 29-bit ID it is 70% of that of Kvaser Air Bridge M12.

It must be noted that the total bus load on each of the CAN bus segments consists of the bus load generated on both sides of the Kvaser Air Bridge M12, 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.

Rule 6. 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 thereby retransmits. At most, a message in the Kvaser Air Bridge will retransmit 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.

Kvaser Air Bridge will introduce additional transfer latency for each retransmission required. The latency will return quickly to normal when the interference disappears or when propagation conditions improve.

Please contact Kvaser support for more detailed information on latency.

Rule 7. Ensure resilience to packet loss

Applications must take into account 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, have 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 kinds 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 'heart beat' messages and such a message is lost, there is a risk of a false alarm issued by a corresponding supervisory mechanism. Therefore, the heart beat interval may need to be shortened so that the alarm timeout period encompasses at least two intervals. Alternatively, the timeout period can be lengthened provided that the supervision response time is acceptable.

4 Message transfer considerations

The recommendations relate to aspects discussed specifically below.

4.1 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 unit will automatically retransmit packets that haven't been acknowledged by the receiving Kvaser Air Bridge unit. 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.

4.2 Transfer capacity

There is also a limit to how many messages can be transferred between two Kvaser Air Bridge units, its transfer capacity, but this is also limited by the bit rate of the connected CAN systems. Assume for example that one of the CAN systems has a lower bit rate than the other, then it is the lowest bit rate that limits the overall throughput. Both CAN systems 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 system.

The transfer capacity of the Kvaser Air Bridge is 250 kbit/s by average for the Kvaser Air Bridge M12. For the Kvaser Air Bridge Light HS, the average capacity depends on the length of the CAN identifier field (11 bits or 29 bits) where the average transfer capacity is 200 kbit/s for the Kvaser Air Bridge M12 and 175 kbit/s for the Kvaser Air Bridge Light HS.

The capacity also depends on the payload length of the CAN frames.

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

4.3 Retransmission

As explained above, interference or low signal level may result in some messages experiencing more latency than others as a result of retransmission and related buffering. The order of the messages is kept 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, preventing transmission or retransmission from taking place on those frequencies. Each Kvaser Air Bridge unit therefore contains a transmit buffer.

For Kvaser Air Bridge Light HS, the number of retransmissions is fixed at 2 whereas Kvaser Air Bridge M12 provides the opportunity to configure the number of retransmissions. For more information see Kvaser Air Bridge Management Interface Description.

4.4 Transmit buffering

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

4.5 Receive buffering

Similar considerations are also relevant for the Kvaser Air Bridge unit that is receiving information. A Kvaser Air Bridge unit 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.

4.6 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 unit is prevented from transmitting (by other signals from nearby radios) there will be additional latency. Likewise, if the transmitting Kvaser Air Bridge unit does not receive an acknowledgement from the other Kvaser Air Bridge unit, 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.

5 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.