

Technical Paper

Common Bluetooth™ API Specification

Danfoss eTRV

This Bluetooth™ API specification is based of the Bluetooth™ cluster library specification. If nothing explicit is mentioned below the commands, clusters and attributes are implemented as per Bluetooth™ Specification



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1. Introduction

Eco2 is an electronic thermostatic radiator valve (eTRV).

Its user interface is split in two:

Primary interface

Consist of a wheel handle, a button, a display and a light ring where basic functions can be done directly at the device including

- Setpoint adjustment
- Enable and disable schedule mode
- Enable and disable pause mode
- Leave and enter mounting mode
- Enable setup mode
- Low battery indication
- Error indications
- Reset to factory defaults

Secondary interface

Bluetooth Low Energy radio interface (BLE) enabling mobile devices to access most of the basic functions listed above and in addition more complex functions, including:

- PIN code
- Schedule
- Vacation
- Display orientation
- Child lock
- Heating regulation modes
- Frost protection
- Firmware upgrade

This document specifies the secondary interface.

It is assumed that the reader of this document has basic knowledge of the Bluetooth standard and BLE in particular and Bluetooths GATT and custom services, and is familiar with how to use Danfoss Eco2 and its accompanying App.

2. Bluetooth support

Eco2 supports Bluetooth Core LE v4.2 using Cypress Pso4 chip (CY8C4128LQI-BL563).

Two standard GATT service are supported:

- Device information service (DIS)

Used to read firmware version and the device name

https://developer.bluetooth.org/gatt/services/Pages/ServiceViewer.aspx?u=org.bluetooth.service.device_information.xml

- Battery service (BAS)

Used to read the current battery level

https://developer.bluetooth.org/gatt/services/Pages/ServiceViewer.aspx?u=org.bluetooth.service.battery_service.xml

Eco2 supports one custom service (ECO2.0 service), which contains 14 characteristics:

- Pin verification
- Thermostat code
- Settings
- Manual Temperature
- Device name
- Bootloader
- EPOC time
- Error code
- Device language
- Setup secret
- Update token
- Schedule part1
- Schedule part2
- Schedule part3

3. Bit and byte order

The Bluetooth standard follows the Little Endian format:

- Byte arrays (multi-octet fields) are transmitted over the air with the least significant byte first.
- The LSB is the first bit of each byte sent over the air

See chapter „1.2 Bit Ordering“ in Bluetooth Specification Version 4.2 [Vol 6, Part B] page 32.

In the following chapters messages exchanged over the interface are defined in tables. The length of the parameters in these tables may be bits, bytes or multi-byte arrays.

For byte arrays the first row in the table defines index 0 in the array.

In tables that defines a list of bits, the first row represents the bits in LSB:

7							0
1	0	0	1	0	1	1	0

4. Encoding

Temperatures and week schedules are encoded as follows.

In order to encode half degrees using integers, temperatures are encoded in one byte as the double of their value:

- 10 -> 5.0°C
- 53 -> 26.5°C
- 56 -> 28.0°C

Schedules in Eco2 have 3 periods each defined by its start and stop time with half an hour resolution, each time encoded in one byte as the double of its value. So a single schedule is encoded into the following 6 byte array definition of Period Type:

Setting	Type	
First period start	byte	0-48 half an hour
First period stop	byte	0-48 half an hour
Second period start	byte	0-48 half an hour
Second period stop	byte	0-48 half an hour
Third period start	byte	0-48 half an hour
Third period stop	byte	0-48 half an hour

If only one period is needed, the first period is used and the parameters for second and third period are set to zero. And if only two periods are needed, the first and second periods are used and the parameters for the third period are set to zero.

The values from the first period start to the third period stop must be in increasing order. A value that does not apply to this rule will not be written, but it will not affect the writing of the other parameters.

5. Encryption

During the Eco2 setup process, the "Setup secret" field is read by the mobile device (see section 10).

After device setup has been completed, all information exchanged over the radio must be encrypted by the mobile device using the [XXTEA algorithm](#) and this shared secret as a 128 bit key for this algorithm.

6. MTU

In order to maintain the standard MTU size (due to Android pre sdk 21), a week schedule is split into three characteristics (see chapters on schedule characteristics).

Also the encryption method selected requires that the length of each characteristic must be a multiple of 4. Characteristics are therefore padded with filler bytes to achieve this (referred to as security padding). Filler bytes should not be parsed, they should be thrown away and not stored after decryption, but re-added before encryption.

7. Advertisement

While Eco2 is powered and not connected to any device it broadcasts messages every 4 seconds indicating that it is ready to connect.

In Bluetooth jargon this means that Eco2 broadcasts ADV_IND packet on each of the 3 broadcasting channels advertising connectable undirected advertising event:

ADV_IND					
Preable (1 byte)	Access Address (4 bytes) Broadcast	Header (2 bytes)	Eco2 MAC address (6 bytes)	Data (0 – 31 bytes)	CRC (3 bytes)
LSB					MSB

The Data field of the message contains the following 3 attributes: [Flags][MAC address][Device Type Name]

7.1 Flags

The flag is 8 bit long

Setting	Type	0 - false, 1 - true
PIN set	bit	PIN required for access. Default false
Battery low	bit	True when voltage is below 2.6V
In setup mode	bit	Set for xx seconds after button push, see chapter "Setup"
not used	bit	<i>reserved</i>
not used	bit	<i>reserved</i>
not used	bit	<i>reserved</i>
not used	bit	<i>reserved</i>
not used	bit	<i>reserved</i>

7.2 MAC address

The MAC constructed from 3 byte Company ID assigned to Danfoss by Bluetooth SIG, plus 3 byte device ID that is unique for each Eco2 and hardcoded within each Cypress chip from the factory:

00:04:2F:xx:xx:xx

7.3 Device Type Name

The Device Type Name cannot be changed using the BLE interface.

The Device Type Name must not be confused with the Device Name that can be accessed using the standard Bluetooth Device Information Service.

For Danfoss Eco2 the Device Type Name is "eTRV".

Each OEM variant has its own unique name.

8. Eco2 Custom Service

UUID: 10020000-2749-0001-0000-00805F9B042F

The Eco2 custom service has the following 14 characteristics:

8.1 PIN verification

This characteristic is used for security to verify that the client is authorised to access the thermostat.

To be allowed to access any service, the first message a mobile device must send is "PIN Verification Write". If the "PIN set" flag is set in the advertisements the correct PIN value must be written. If the pin does not match the set pin, an error is returned. Otherwise the read or write will return success.

If the "PIN set" flag is unset, any PIN value will do.

It is enough to write "PIN Verification" once in the beginning of each connection for the whole duration of the connection.

The PIN verification messages should not be encrypted.

4 bytes

Write with response

UUID: 10020001-2749-0001-0000-00805F9B042F

Setting	Type	
Pin	UInt32	Default 0000

8.2 Thermostat code

This characteristic is used to change the pin code

4 bytes

Read + Write with response

UUID: 10020002-2749-0001-0000-00805F9B042F

Setting	Type	
Pin	UInt32	Default 0000
Pin set	Byte	PIN required for access. 0 - false, 1 - true, Default false
Security Padding	Byte	3 bytes of 0's

8.3 Settings

16 bytes

Read + write with response

UUID: 10020003-2749-0001-0000-00805F9B042F

Setting	Type	
Child lock	bit	0 - off, 1 - on
Mounted	bit	0 - not mounted, 1 - mounted
Calibrated	bit	0 - off, 1 - on
Reaction time	bit	0 - Quick, 1 - Moderate
Display rotation	bit	0 - horizontal, 1 - vertical
Thermostat orientation	bit	0 - horizontal, 1 - vertical
Daylight saving	bit	0 - off, 1 - on
Forecast	bit	0 - off, 1 - on
Min	byte	10 - Max
Max	byte	Min - 56
Frost	byte	8 - 20
Mode	byte	Bit values: 0 - manual, 1 - schedule, 2 - vacation, 4 - RESERVED
Vacation	byte	10 - 56
Vacation start	UInt32	EPOC time. 0 if not set
Vacation end	UInt32	EPOC time. 0 if not set
Security Padding	bytes	2 bytes of 0's

8.4 Manual Temperature

The response equals the written value.

8 bytes

Read + write with response

UUID: 10020005-2749-0001-0000-00805F9B042F

Setting	Type	
Temp - set point	byte	10 – 56
Room temp	byte	0 - 255 Read only
Security Padding	bytes	6 bytes of 0's

8.5 Device name

The name written must be used as the device name

16 bytes

Read + Write with response

UUID: 10020006-2749-0001-0000-00805F9B042F

Setting	Type	
Name	utf8string	Unused bytes are 0x0
Security Padding	byte	1 byte of 0

8.6 Bootloader

Use to tell Eco2 to restart in bootloader mode by writing the secret that was read in setup mode. See more detail in chapter about Firmware Upgrade

16 bytes

Write with response

UUID: 10020007-2749-0001-0000-00805F9B042F

Setting	Type	
Setup secret	bytes	Regardless of the written value, the thermostat will acknowledge whether or not it will restart in boot loader mode in its response: 1 means that it will disconnect and restart in boot loader mode, 0 means that it will not.

8.7 EPOC time

8 bytes

Read + Write with response.

UUID: 10020008-2749-0001-0000-00805F9B042F

Setting	Type	
Current time	Bytes	EPOC time (4 bytes). 0 if new thermostat
Offset Signed	Int32	Offset in seconds since UTC

8.8 Error code

Return error if invalid. This characteristic is used to read error codes.

8 bytes

Read

UUID: 10020009-2749-0001-0000-00805F9B042F

Setting	Type	
Error code	UInt16	Error flags
Security Padding	Bytes	6 bytes of 0's

8.9 Device language

8 bytes

Write

UUID: 1002000A-2749-0001-0000-00805F9B042F

Setting	Type	
Country code	Int16	ISO 639-1 Code in UTF8
Security Padding	bytes	6 bytes of 0's

8.10 Setup secret

This is only available to read when the thermostat is in setup mode (the “In setup mode” flag is set in advertisement).

See details in chapters about “Setup” and “Firmware Upgrade”.

16 bytes

Read

UUID: 1002000B-2749-0001-0000-00805F9B042F

Setting	Type	
Setup secret	Bytes	Bytes specifying the secret

8.11 Update token

See more detail in chapter about Firmware Upgrade

12 bytes

Read

UUID: 1002000C-2749-0001-0000-00805F9B042F

Setting	Type	
Device token	Bytes	Token to send to the firmware cloud update service

8.12 PIN Schedule part1

See definition of “Period” type in chapter “5. Encoding”

20 bytes

Read + write with response

UUID: 1002000D-2749-0001-0000-00805F9B042F

Setting	Type	
At home temperature	byte	10-56
Away temperature	byte	10-56
Monday schedule	Period	6 bytes
Tuesday schedule	Period	6 bytes
Wednesday schedule	Period	6 bytes

8.13 PIN Schedule part2

See definition of “Period” type in chapter “5. Encoding”

12 bytes

Read + write with response

UUID: 1002000E-2749-0001-0000-00805F9B042F

Setting	Type	
Thursday schedule	Period	6 bytes
Friday schedule	Period	6 bytes

8.14 PIN Schedule part3

See definition of “Period” type in chapter “5. Encoding”

12 bytes

Read + write with response

UUID: 1002000F-2749-0001-0000-00805F9B042F

Setting	Type	
Saturday schedule	Period	6 bytes
Sunday schedule	Period	6 bytes

9. Examples

9.1. Settings

Example bytes: [0x5c, 0x11, 0x19, 0xA, 0x1, 0x2, 0x576B9700, 0x576E7240]

Parsed values:

Setting	Value
Child lock	0 - off, 1 - on
Mounted	0 - not mounted, 1 - mounted
Adaptive control	0 - off, 1 - on
Reaction time	0 - Quick, 1 - Moderate
Display rotation	0 - horizontal, 1 - vertical
Thermostat orientation	0 - horizontal, 1 - vertical
Daylight saving	0 - off, 1 - on
Forecast	0 - off, 1 - on
Min	17
Max	25
Frost	10
Mode	0 - manual, 1 - schedule, 2 - vacation
Vacation	24
Vacation start	Jun 23, 2016, 08:00 AM UTC
Vacation end	Jun 25, 2016, 12:00 PM UTC

9.2. Period type

Example bytes:

Period 1: [0x01, 0x09, 0x10, 0x18, 0x26, 0x2E]

Period 2: [0x00, 0x08, 0x10, 0x1E, 0x1E, 0x2F]

Parsed values:

Period	Period 1	Period 2
First period start	0:30	0:00
First period stop	4:30	4:00
Second period start	8:00	8:00
Second period stop	12:00	15:00
Third period start	19:00	15:00
Third period stop	23:00	23:30

9.3. Manual Temperature

Example bytes: [0x16, 0x19]

Parsed values:

Setting	Value
Temp - set point	22
Room temp	25

9.4. Thermostat code

Example bytes: [0x163C]

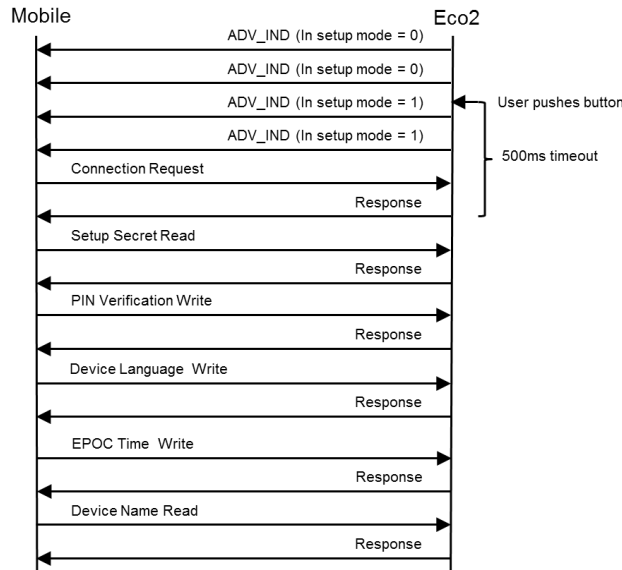
Parsed values:

Setting	Value
Thermostat code	5-6-9-2
Pin set	1

10. Setup

Bluetooth defines the concept of “pairing”. The Bluetooth pairing concept is not used in Eco2. However, Danfoss has implemented its own feature called “Setup” that has similar role as pairing. Both the words “setup” and “pairing” are used in this document, and always refer to Danfoss proprietary “Setup” feature.

When the button on Eco2 is pushed the “In setup mode” bit is set for the next 0.5 seconds in all advertisement packets, telling the receiver which Eco2 the user wants to pair to. The setup process is as follows:



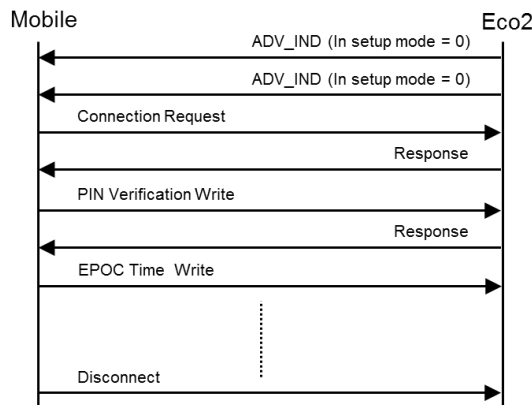
The receiving mobile saves the following information

- MAC address (from Advertisement)
- Setup secret (from Setup Secret)
- PIN (from PIN Verification)
- Device name (from Device Information Service)

This information is used each time the mobile device wants to connect to this Eco2 in the future.

11. Connecting

A mobile device can connect to Eco2 that it has “paired” to earlier if it is within its range and it is powered and unconnected. To be allowed to access any service, the first message a mobile must send is “PIN Verification Write”. If the “PIN set” flag is set in the advertisements the correct PIN value must be written. If the “PIN set” flag is reset, any PIN value will do. It is enough to write “PIN Verification” once in the beginning of each connection for the whole duration of the connection.



12. Firmware Upgrade

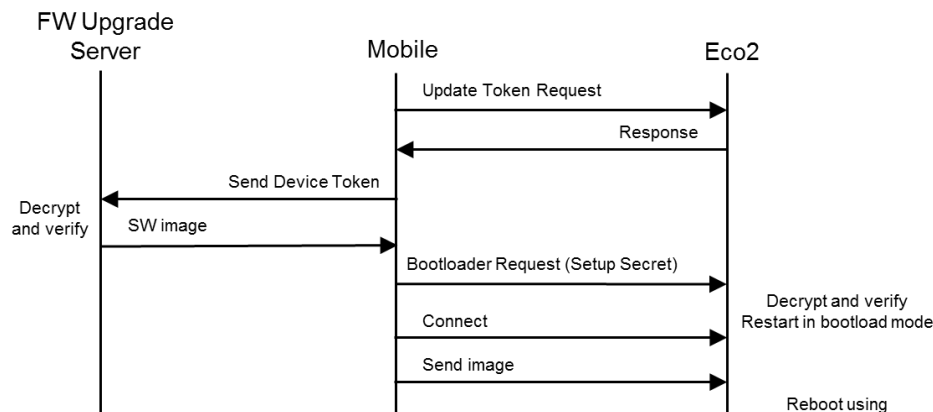
Eco2 and its OEM variants can be firmware upgraded to correct bugs and introduce improvements.

Details about the firmware upgrade process needs to be agreed between Danfoss and OEM partners.

The following description outlines the firmware upgrade process.

A Danfoss firmware upgrade server is available on public Internet (in the cloud) that will offer a newer firmware image to Eco2s based on rules operating on different parameters received from Eco2. It is the mobile device, or its user, that takes the final decision to accept new firmware from the server.

The Eco2 creates a message containing a range of different parameters and encrypts it with a key it shares with the Firmware Upgrade server into a "Update Token". The process starts when the mobile device asks Eco2 for the token and sends it to the Firmware Upgrade server. The server decrypts the token and based on its contents makes a decision if Eco2 should be upgraded and which firmware image to use. It sends the firmware image to the mobile device. The mobile authenticates itself to Eco2 using the Setup Secret it got from it when they paired, and requests the Eco2 to reboot in bootloader mode. When in boot loader mode, the mobile connects to Eco2 again, sends the raw image over the air (OTA) and Eco2 reboots using the new firmware.



13. Battery lifetime of ECO II

Be aware that the BLE interface used on ECO II is original designed to be used as an advanced user interface on a smartphone and therefor would the users seen over long time only connect seldom to ECO II probably on average a few times a month. If the information in this document is used to design and set up a gateway which is connected to a system that manage an overall system it is easy to setup that this system should connect to the thermostat at a much shorter interval. If this is done is will reduce the battery lifetime of the ECO II. An overall recommendation will be to have the average number of connections to the ECO II thermostat during a day below 10 times. If the average number of connections go above it will reduce the battery lifetime to a level which may annoy users of the ECO II thermostat.

These 10 times a day is based on that each connection time is up to max 2 seconds used to make connection, read data and write data to the ECO II thermostat and close the connection again. If the connection time can be held below 1 second can the number of times a connection is made per day be raised to around 20 times.

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