RED beet rev.1.1 is a universal powerline module based on Qualcomm's QCA7005 chip supporting HomePlug GreenPHY standard. There are 3 different versions of the module and despite primary focus on e-mobility (EVSE and PEV) it also perfectly fits for smart grid, smart meter, IoT and other long-range communication applications. All modules come with extended industrial temperature range making it suitable even for high-end automotive applications. Low noise floor and optimized line coupling circuitry with custom components including 1:1:1 and 1:4:5 ratio transformers and 4 kV overvoltage protection.

Available for purchase from CODICO GmbH

Quick specs

- Based on QCA7005
- Extended industrial temperature range (up to 95 °C)
- SPI and GPIO interfaces to QCA7005
- Modified powerline chipset QFN package for easy optical inspection
- Single side, SMD module
- Comes in 3 different configurations: PEV (plug-in electric vehicle), EVSE (electric vehicle supply equipment) and EN50561-1 (long range powerline communication)
- Small form factor (23 x 23 x 4 mm)

Table of Contents

1. Features

TABLE 1-1. RED BEET REV.1.1 FEATURES

	RED beet H rev.1.1	RED beet E rev.1.1	RED beet P rev.1.1
Powerline chip	QCA7005		
Firmware version	Qualcomm HomePlug GreenPHY FW v3.0		
Configuration (PIB)	EN 50561-1	EVSE	PEV
Host interface	SPI (default)		
Power supply	3.3V		
Power consumption	1 W (at 25º C)		
Mains coupling on board	No		
Max data rate	9.8 Mbps PHY rate / 4.7 Mbps UDP data rate		
Max distance	300 meters	According to ISO/IEC 15118-3	
Temperature range	-40º C to +95º C (board temperature)		
Size	23 x 23 x 4 mm		
Weight	2.8 ±0.1 g		
Applications	IoT, home control, appliances, smart plugs, building and industrial automation, smart grid, electric meters, water heaters	Electric vehicle charging stations	Plug-in electric vehicles (on board)
Ordering number	RED-BEET-H 1.1	RED-BEET-E 1.1	RED-BEET-P 1.1

2. Block diagram

FIGURE 2-1. RED BEET REV.1.1 MODULE BLOCK DIAGRAM
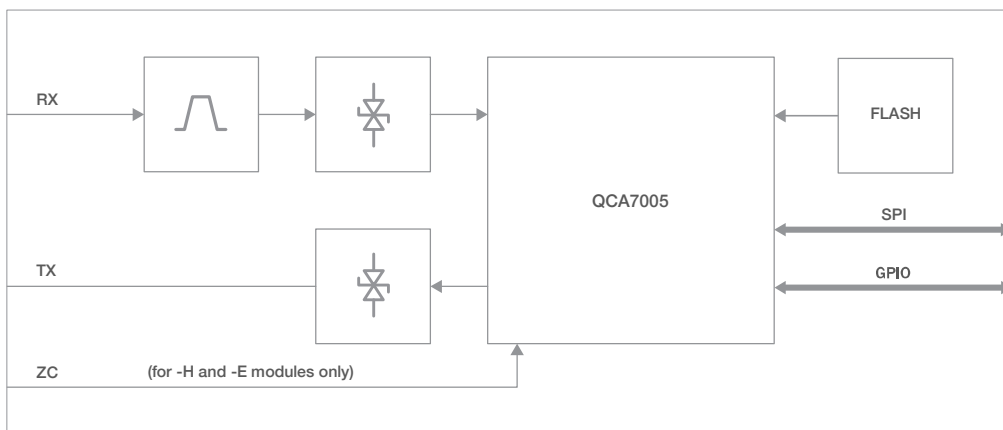
3. Operating conditions

TABLE 3-1. STANDARD OPERATING CONDITIONS

Parameter	Min	Typical	Max	Units
VDD, SERIAL, GPIO	3.13	3.3	3.46	V
Operating temperature (board)	-40	-	95	°C
Ambient temperature	-40	-	85	°C

TABLE 3-2. ABSOLUTE MAXIMUM RATINGS

Parameter	Min	Typical	Max	Units
VDD, SERIAL, GPIO	-0.3	-	3.6	V
Operating temperature (board)	-40	-	95	°C
Storage temperature	-40	-	150	°C
RESETN active pulse duration	100	-	-	us

TABLE 3-3. RED BEET REV.1.1 MODULE POWER CONSUMPTION (+25ºC AMBIENT TEMPERATURE)

Operation mode	Typical	Units
Transmit Mode	1000	mW
Receive Mode	700	mW
Idle Mode (no communication)	330	mW
RESETN Pin Active Mode	200	mW
Sleep Mode (power saving mode)	100	mW

NOTE: Operation at maximum temperature limit may increase power consumption up to 25%.

RED beet rev.1.1 power supply should have extra 25% power margin and be capable of providing power up to 1600 mW

TABLE 3-4. ZERO-CROSS DETECTOR INPUT SIGNAL SPECIFICATION

Parameter	Min	Typical	Max	Units
AC mains frequency (F)	48.4 57.7	50 60	51.6 62.3	Hz
Active high / low time	0.4 0.4	10.0 8.3	19.6 16.2	ms
Rise / fall time	0.001	-	-	ms
Offset from zero-crossing	0 0	- -	20.0 16.6	ms
Peak to peak voltage	0.1	0.25	3.3	V

NOTE: Zero-cross detector input signal has to have a nominal frequency of 50 or 60 Hz.

4. Module pinout and pin description
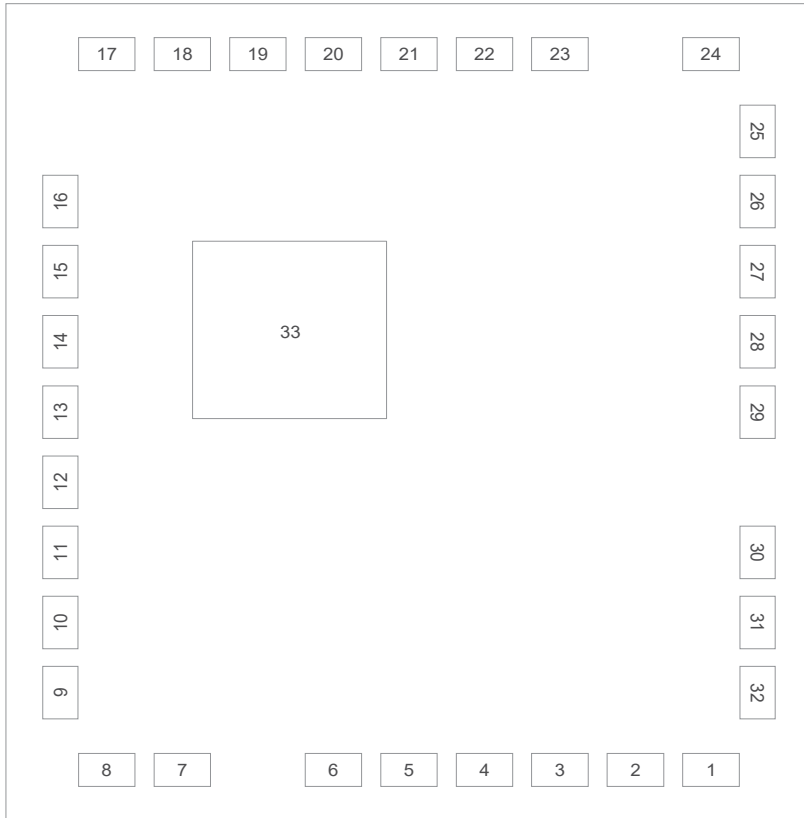
FIGURE 4-1. PIN ASSIGNMENTS (BOTTOM VIEW)

TABLE 4-1. PIN DESCRIPTION

Pin number	RED beet H 1.1	RED beet E 1.1	RED beet P 1.1	Type	Description
1	GND			-	Ground connection
2	GND			-	Ground connection
3	GND			-	Ground connection
4	GND			-	Ground connection
5	GND			-	Ground connection
6	GND			-	Ground connection
7	GND			-	Ground connection
8	VCC			-	3.3V power supply
9	GND			-	Ground connection
10	GND			-	Ground connection
11	GND			-	Ground connection
12	GPIO_0			I/O	PU (10 kOhm) - boot from Flash

TABLE 4-1. PIN DESCRIPTION (CONTINUATION)

Pin number	RED beet H 1.1	RED beet E 1.1	RED beet P 1.1	Type	Description
13	GPIO_1			I/O	PD (10 kOhm) - required for QCA7005
14	GPIO_2			I/O	PU (10 kOhm) - SPI burst mode
15	GPIO_3			I/O	Input (push button)
16	RESETN			I	Reset (active low)
17	GND			-	Ground connection
18	SERIAL_IO_4			I	MOSI (default)
19	SERIAL_IO_3			O	MISO (default)
20	SERIAL_IO_2			I	SPI CS (default)
21	SERIAL_IO_1			I	SPI CLK (default)
22	SERIAL_IO_0			O	SPI INT (default)
23	GND			-	Ground connection
24	GND			-	Ground connection
25	GND			-	Ground connection
26	GND			-	Ground connection
27	GND			-	Ground connection
28	RXN			I	Powerline receive input negative
29	RXP			I	Powerline receive input positive
30	TXN			O	Powerline transmit output negative
31	TXP			O	Powerline transmit output positive
32	ZC_IN	ZC_IN	GND	I	Zero-cross detector input
33	THERMAL PAD (GND)			-	Thermal pad with a connection to Ground plane

NOTE: Thermal pad shall have a good connection to the Ground plane for a better heat dissipation. It is recommended to have 9 vias 0.3 mm in diameter (formed as a square of 3x3 vias) to a Ground layer which spreads heat all along the PCB.

TABLE 4-2. BOOT STRAP GPIO CONFIGURATION

GPIO number	Function	PU (pull-up)	PD (pull-down)
GPIO_0	Boot source	Flash	Host
GPIO_1	Host interface	-	SPI slave
GPIO_2	SPI slave mode	Burst	Legacy
GPIO_3	None	-	-

**NOTE:** PU/PD resistor values 10 kOhm in all cases.
There are PU/PD resistors installed on the module already. GPIO_0 and GPIO_2 are pulled-up (PU) and GPIO_1 is pulled-down (PD).

TABLE 4-3. GPIO FUNCTIONS (AFTER BOOT UP)

| GPIO number	Type	Function
GPIO_0	Output	LED: PLC link and simple connect statuses
GPIO_1	Output	LED: PLC RX/ TX status
GPIO_2	Output	LED: throughput indication
GPIO_3	Input	Push button: - Simple connect: 0.5 to 3s hold time - NMK randomization: 5 to 8s hold time - Factory defaults: 10 to 15s hold time

NOTE: All above specified settings are for QCA7005 FW v3.0

FIGURE 4-2. GPIO LED SCHEMATIC PROPOSAL (GPIO_0, GPIO_1, GPIO_2)
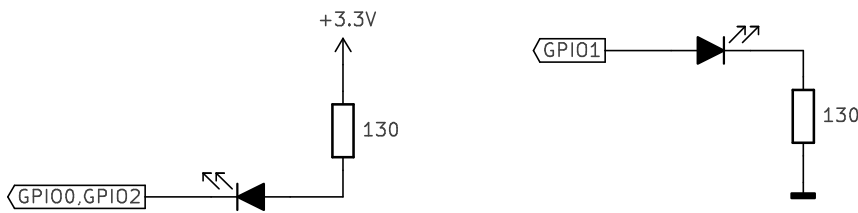
NOTE: Typically LEDs are only required for Home control applications (RED beet H rev.1.1 module **only**)

FIGURE 4-3. PUSH BUTTON SCHEMATIC PROPOSAL (GPIO_3)
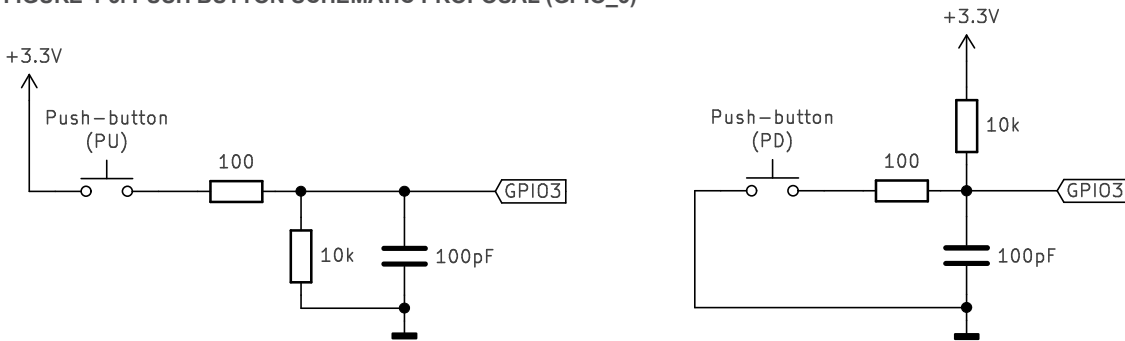
NOTE: Typically Push-button is only required for Home control applications (RED beet H rev.1.1 module **only**)

TABLE 4-5. SERIAL CONFIGURATION OPTIONS

	SPI (default)	UART
SERIAL_IO_0	Interrupt	
SERIAL_IO_1	CLK	
SERIAL_IO_2	CS	
SERIAL_IO_3	MISO	TXD
SERIAL_IO_4	MOSI	RXD

NOTE: SPI interface is a default and only recommended interface. In the bootloader the only available interface is SPI.

TABLE 4-6. UART SETTINGS

Setting	Value
Maximum recommended baud rate	57600
Data bits	8
Parity	None
Stop bits	1
Flow control	None

QCA7005 supports SPI Mode 3 (Motorola-SPI standard), where both CPOL (clock polarity) and CPHA (clock phase) are set to 1 (clock cycle idles at 1 and consists of a pulse of 0, data valid at raising edge of clock). QCA7005's maximum slave SPI clock frequency is 12 MHz.

When an out-of-sync condition happens, the SPI host needs to reset QCA7005 in order to sync up and go back to the normal operation.

The preferred mode of SPI operation is Burst Mode to eliminate external RESET operation.

To reset QCA7005, the SPI host can issue register write to the bit [6] of SPI-CONFIG register.

Software resources

QCA7000/5 SPI driver is a part of Linux kernel since v3.18. QCA7000/5 driver forwards Ethernet frames between Ethernet and SPI interfaces using HAL drivers.

Various application notes, including the ones for SPI device driver, PIB (Parameter Information Block) configuration for different application, PSD calibration and Noise measurements, and other materials could be found on CODICO PLC documentation area:

https://downloads.codico.com/misc/plc

RED beet rev.1.1 module as well as other HomePlug AV/GreenPHY devices could be configured and controlled using a set of command line tools open-plc-utilities. Source codes of open-plc-utilities and manuals could be found on Github repository:

https://github.com/qca/open-plc-utils

Zero-cross detection in various applications

Zero-cross detection has to be used in all applications with communication over AC mains or when module's power supply is powers from AC mains. Two or more HomePlug AV/GreenPHY logical networks can only coexist when zero-cross detection circuit is implemented.

Use of zero-cross detection is mandatory in all types of EVSE applications (including AC and DC charging stations). Reference circuits for zero-cross detection are shown in Chapter 5.

5. Powerline and zero-cross connection

Zero-cross detection has to be used in all applications with communication over AC mains or when module's power supply is powers from AC mains. Two or more HomePlug AV/GreenPHY logical networks can only coexist when zero-cross detection circuit is implemented.

Use of zero-cross detection is mandatory in all types of EVSE applications (including AC/DC/CCS charging stations). RED beet H 1.1, RED beet E 1.1 and RED beet P 1.1 modules require an external powerline coupling and zero-cross detector circuit (for RED beet H 1.1 and RED beet E 1.1 only). Reference design schematics for all 3 options of RED beet rev 1.1 modules (H, E and P) are presented on Figures 5-1, 5-2 and 5-3 accordingly.

Coupling circuit for **RED beet H 1.1** module (Figure 5-1) is designed for connection to AC or DC power lines with voltage up to 250Vrms. Circuit protection (such as Varistor/MOV, Fuse) is required extra, but not shown on the reference schematic. Junction capacitance of circuit projection has to be less than 10pF.
Please note 2 coupling transformers with different pinouts. YT-35935 is recommended to be used, it has Tx pair routed to the inner pins of transformer.

FIGURE 5-1. RED-BEET-H REV.1.1 CIRCUITS FOR COUPLER AND ZC DETECTOR
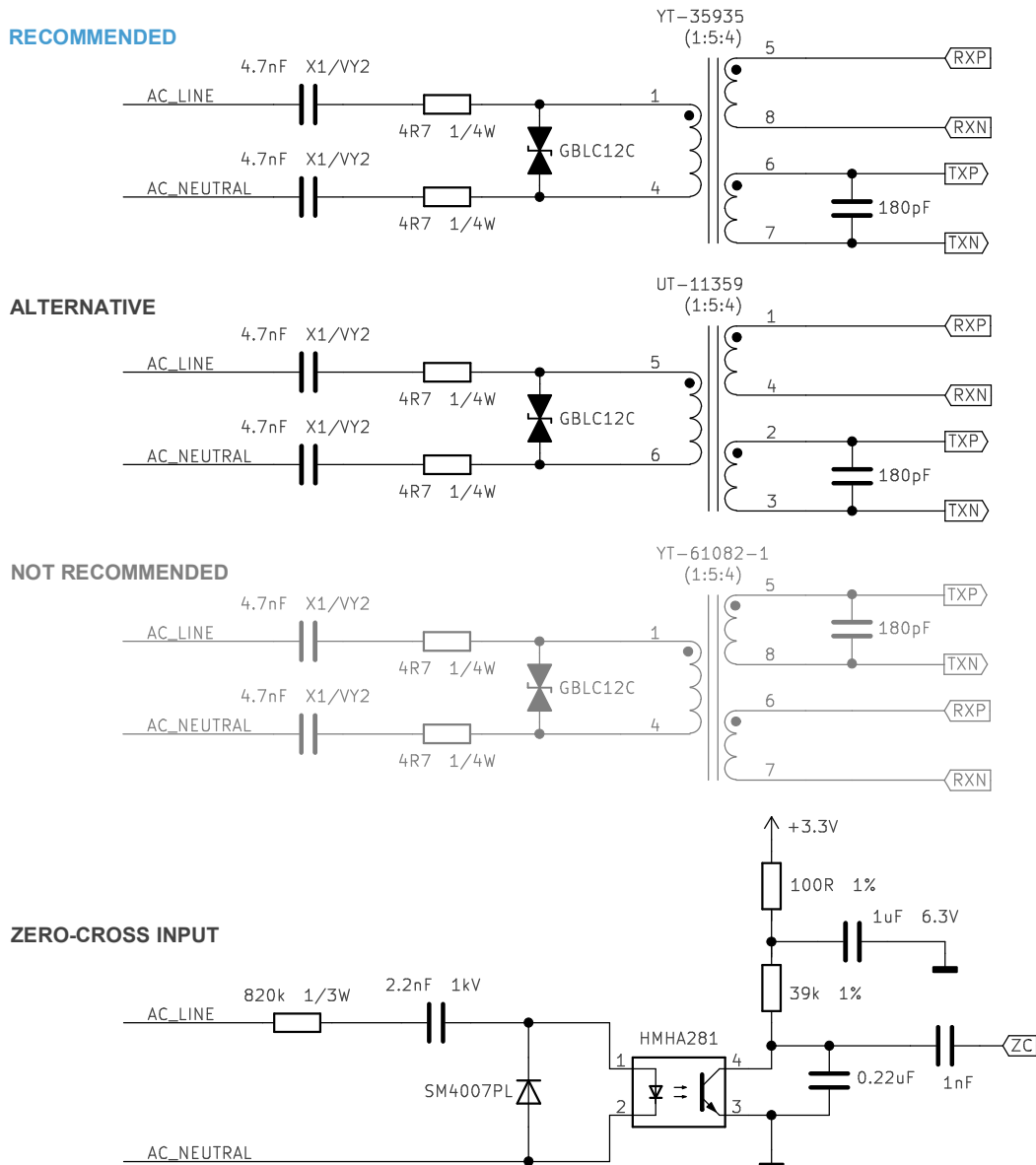
Zero-cross circuit for connecting to AC mains with voltage up to 250Vrms (RED beet H 1.1 and RED beet E 1.1) does not contain a circuit and surge protection, but it should be implemented extra (such as Varistor / MOV, Fuse, TVS diode).

Please note that for **RED beet H 1.1** and **RED beet E1.1** designs it is also recommended to implement LISN (line impedance stabilization network) circuit in fron of zero-cross detector, a reference circuit is shown on Figure 5-4.

Coupling circuit for **RED beet E/P rev.1.1** modules (Figures 5-2 and 5-3) is designed for use on CP/PE (Control Pilot / Protective Earth) in e-mobility applications and tolerant to +12/-12V PWM 1kHz signal. PLC signal surge protection (3V rated TVS diode with 3pF junction capacitance) is shown on the schematic, but surge protection for CP for PWM 1kHz related circuit should be considered extra, it is highly recommended to use 12V rated TVS diode with junction capacitance less than 10pF (e.g. GBLC12C).

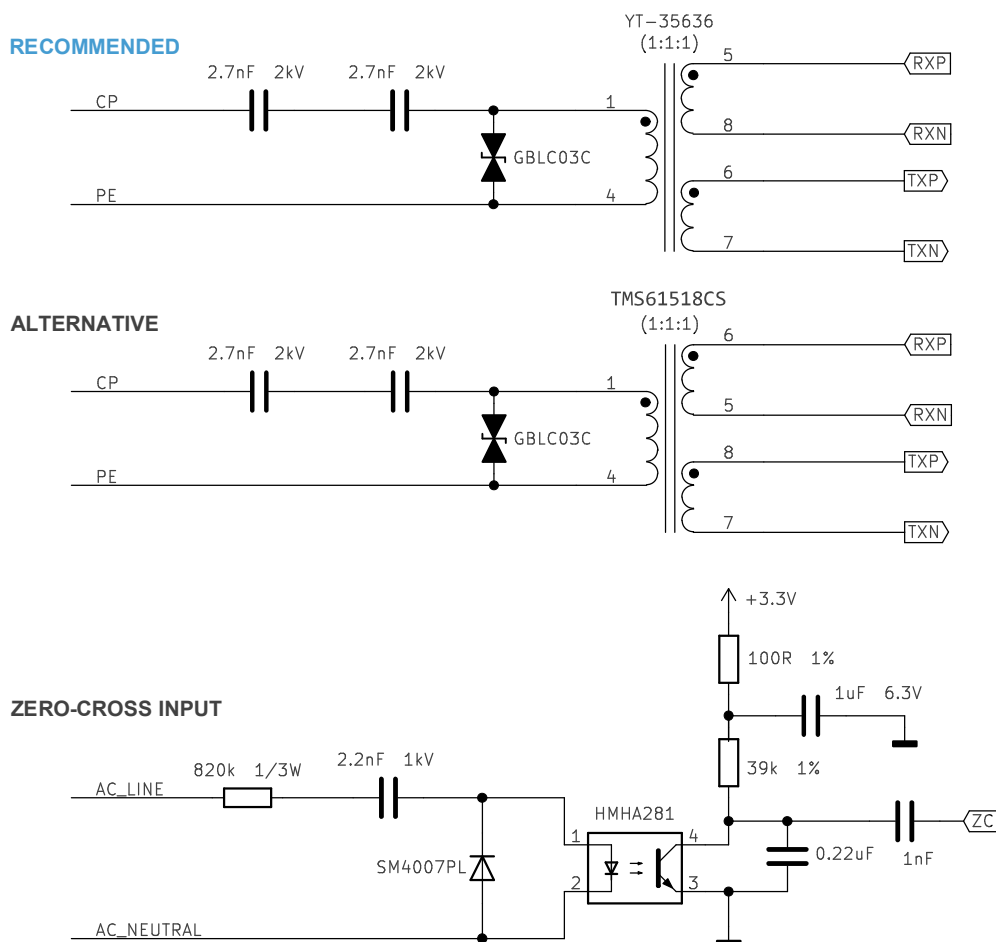**FIGURE 5-2. RED-BEET-E REV.1.1 CIRCUITS FOR COUPLER AND ZC DETECTOR**
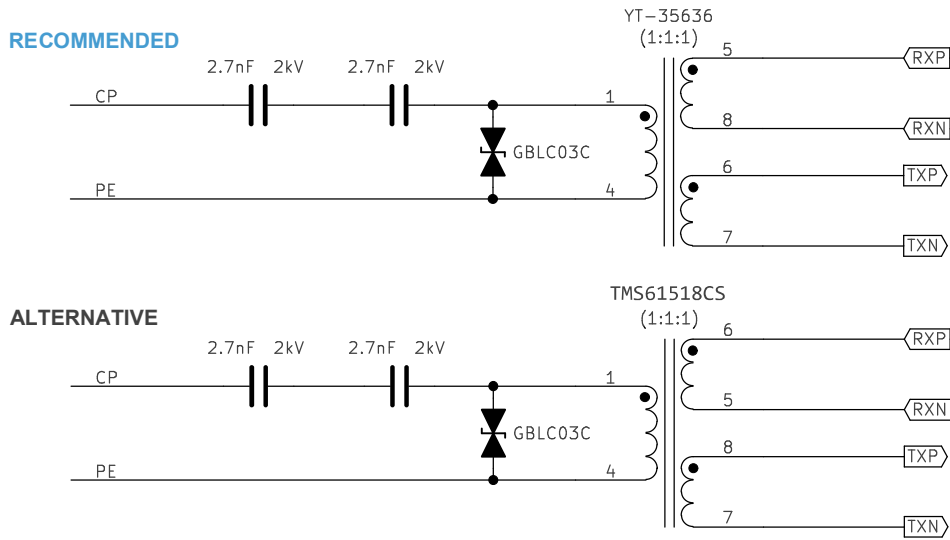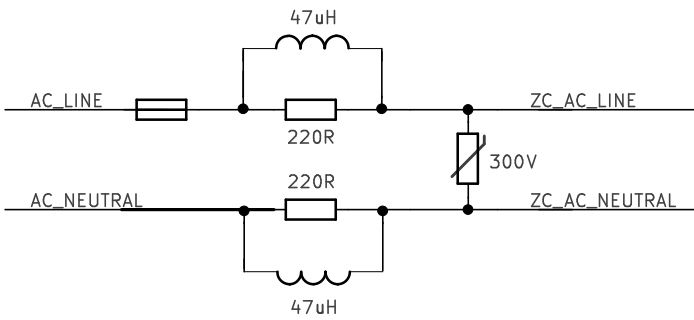
FIGURE 5-3. RED-BEET-P CIRCUIT FOR COUPLER

RECOMMENDED

YT–35636
(1:1:1)

CP — 2.7nF 2kV — 2.7nF 2kV — 1 — GBLC03C
PE — 4

5 — RXP
8 — RXN
6 — TXP
7 — TXN

ALTERNATIVE

TMS61518CS
(1:1:1)

CP — 2.7nF 2kV — 2.7nF 2kV — 1 — GBLC03C
PE — 4

6 — RXP
5 — RXN
8 — TXP
7 — TXN

FIGURE 5-4. LISN (LINE IMPEDANCE STABILIZATION NETWORK) CIRCUIT FOR ZERO-CROSS DETECTOR

47uH

AC_LINE ——[ ]—— 220R —— ZC_AC_LINE
                              300V
AC_NEUTRAL —— 220R —— ZC_AC_NEUTRAL

47uH

Transformers and TVS diodes used in the designs below are available for purchase from CODICO GmbH: https://www.codico.com

6. Power supply reference design

On the Figure 6-1 there is a reference design schematics for RED beet rev.1.1 power supply.

FIGURE 6-1. RED BEET REV.1.1 POWER SUPPLY RECOMMENDATION
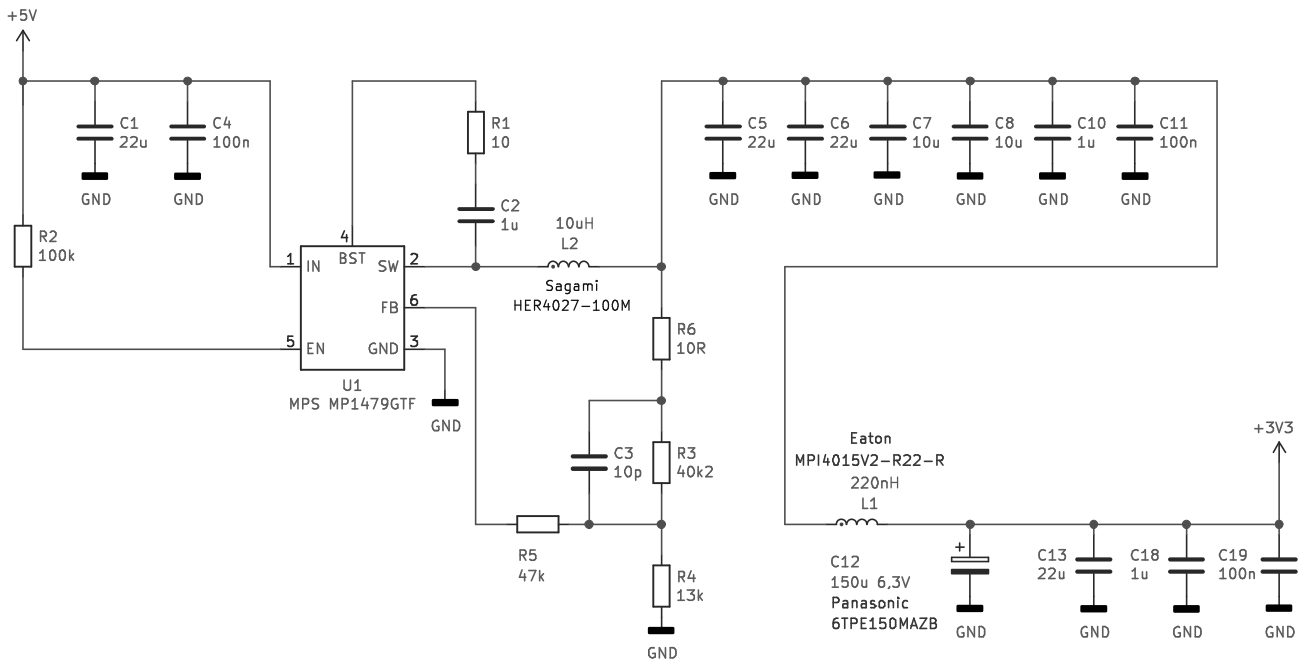
The recommended design of +3.3V power supply for RED beet rev 1.1 module based on MP1479 has very low level of noise and ripple. The nominal input voltage of the power supply is +5V DC, however it also can work in a broad input voltage range from +4.5V to 15V DC.

When +5V input voltage is used, 22uF C1 should be MLCC. In case input voltage is higher (e.g.+12V), MLCC is not sufficient because of DC bias derating, therefore 22uF C1 should be changed to Tantal Polymer capacitor and in addition 1uF C1a MLCC should be added in parallel to C1 for low ESR (use X7R type capacitor).

Note: Circuit protection and EMI filter for DC-DC power supply input are not shown on Figure 6-1 and if required, have to be implemented extra.

7. Layout design rules

1. TX traces between the module and transformer should be as short as possible, routed in as differential pairs (with 100 Ohm differential impedance matching). Trace width should be at least 0.2 mm.
Total individual trace length should not exceed 10 mm.

2. TX traces between the RED beet rev.1.1 pins and coupling transformer must be length matched within 5%.

3. RX traces between the RED beet rev.1.1 pins and coupling transformer must be length matched within 5%.

4. RED beet rev.1.1 module must not be placed near components that carry power supply switching currents.

5. Absolutely no digital traces are allowed to traverse area underneath RED beet rev.1.1 module on any layer. Electromagnetic pulses (EMP) of the trace currents will be induced onto the RX and TX traces.

6. All inductors on the board must be shielded. Put Ground in layout underneath of the inductors.
Connect the start of the winding to the switching node.

7.Place ground guards against any currents passing under the analog section on any PCB layer.

8. Keep all DC-DC switching regulators and power planes well away from RED beet rev.1.1 module.

9. Thermal pad shall have a good connection to the Ground plane for better heat dissipation. It is highly recommended to have 9 vias 0.3 mm in diameter (formed as a square of 3x3 vias) to a Ground layer which spreads heat all along the PCB. But do not cover the whole copper area underneath of thermal pad with a soldering paste, make sections as it is shown on Soldering paste footprint on page 15.

10. Length of SPI interface wires should be not longer than 10 cm.

11. Place the high-current paths of power supply (Ground, input voltage, switch output) absolutely close to the switching regulator with short, direct, and wide traces.

12. Place the input capacitor as close to the input voltage of power supply and Ground as possible (recommended to use 1 mm width traces) with a low impedance connection to minimize the antenna loop area.

13. Keep the switching node of power supply switching regulator IC small. Route switch output away from sensitive analog areas, such as feedback line.

14. Place the external feedback resistors as close to Feedback pin of switching regulator as possible. Keep all feedback connections short and direct. Keep away from the switching node.

15 It is recommended to place the filter components of power supply on the bottom side, shielded from the noisy switching circuits by the Ground plane.

16. Distance is required between the noisy source, filter components, and the post filter circuits of power supply. Shielding can replace distance.
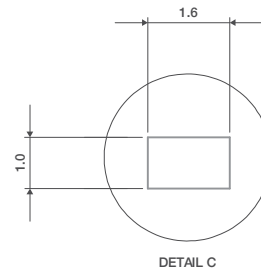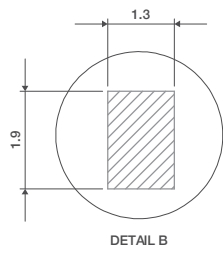
8. Module marking information

Model: RED beet H 1.1

MAC: C493000FEA47

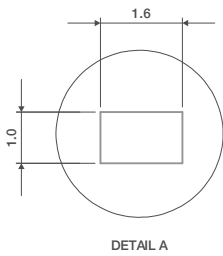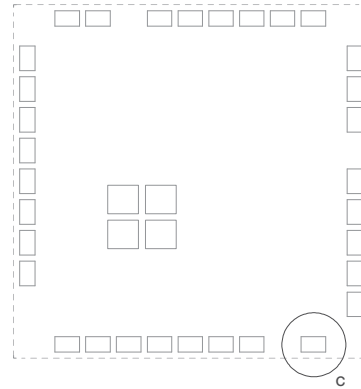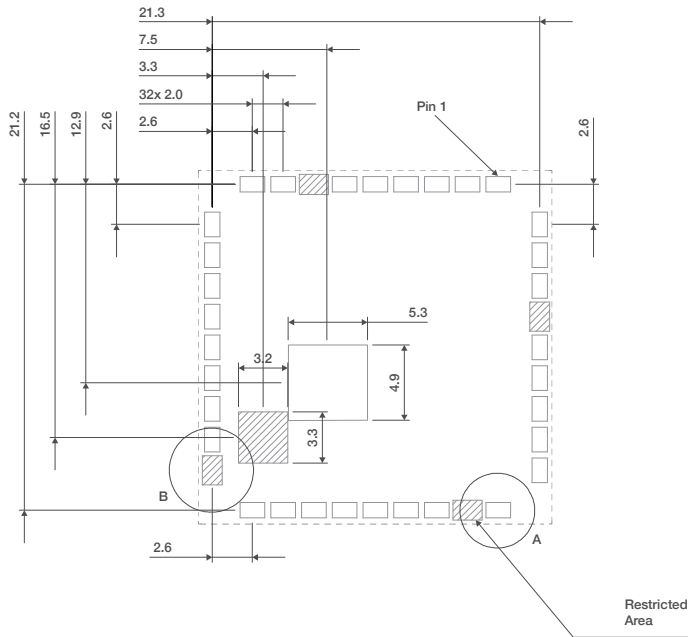SN: PWL1201172000001

Made in EU

Each module is marked with a label containing the following data:

1. Ordering code

2. QCA7005 MAC Address (contains no separator, OUI C49300)

3. Serial Number in a format PWL100VWWYYNNNNNN, where:

PWL120	- product code for RED beet rev.1.1
V	- version of module (1 for -H, 2 for -E, 3 for -P)
WWYY	- date code as a calendar week of production followed by a year
NNNNNN	- serial number in a production lot

4. QR-code containing MAC Address

5. Additionally each label contains 8Devices logo which also indicates pin 1 position

9. Mechanical characteristics

TOP VIEW

23.0

23.0

SIDE VIEW

4.2

1.0

PERSPECTIVE VIEW

BOTTOM VIEW

19.5
15.5
5.5
3.5

19.5
7.5
5.5
0.9

3.5
5.5
11.5
15.5
17.5
19.5

17 18 19 20 21 22 23 24

33

3.5
5.5
9.5
11.5
19.5

A

1.6

1.0

DETAIL A

PCB footprint   Soldering paste footprint

TOP VIEW

DETAIL A

DETAIL B

DETAIL C

10. Reflow profile information

Reflow profile recommendation

Ramp up rate	3°C/second max
Maximum time maintained above 217°C	120 seconds
Peak temperature	250°C
Maximum time within 5°C of peak temperature	20 seconds
Ramp down rate	6°C/second max

Reflow profile
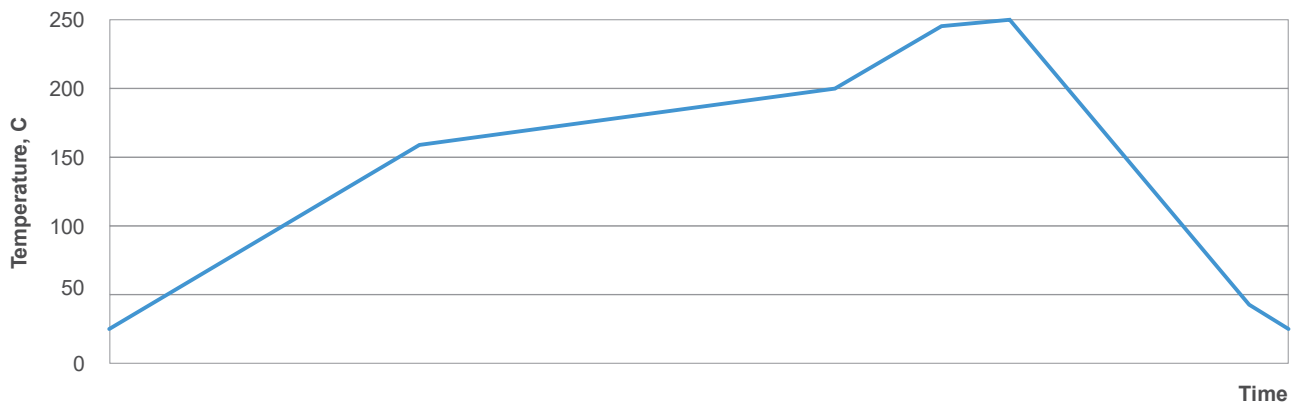
11. Evaluation boards

In order to evaluate HomePlug AV/GreenPHY PLC technology and RED/YELLOW beet modules operation in particular, there is a set of evaluation boards available:

CARRIER board - contains RED beet module configured for one of the applications: Home Control, Automotive EVSE and PEV sides. It comes with line coupling for e-mobility applications or for working on mains.
A standard 20-pin header connector is available for connection to an external MCU via SPI. For more details please refer to CARRIER board datasheet.

COMM board - contains STM32F745 MCU which has QCA7005 driver implemented and depends on the embedded firmware, it can:

- operate as interface converter between QCA7005 SPI and a number of interfaces available on STM32 MCU (including Ethernet and USB)
- support SLAC for automotive applications (EVSE and PEV)
- run ISO/IEC 15118 software stack for e-mobility charging applications
- be used for ISO/IEC 15118 stack implementation development base on Sevenstax SDK

Communication board has Ethernet, USB, CAN, SPI and UART interfaces available.
For more information please refer to COMM board datasheet.

CARRIER and COMM boards could be used individually or as a joint set of evaluation boards.

12. Packaging and ordering information

RED beet rev.1.1 modules are packed into trays. Each tray fits 54 modules. Every 5 trays are vacuum sealed and one standard packing box contains 1350 modules.

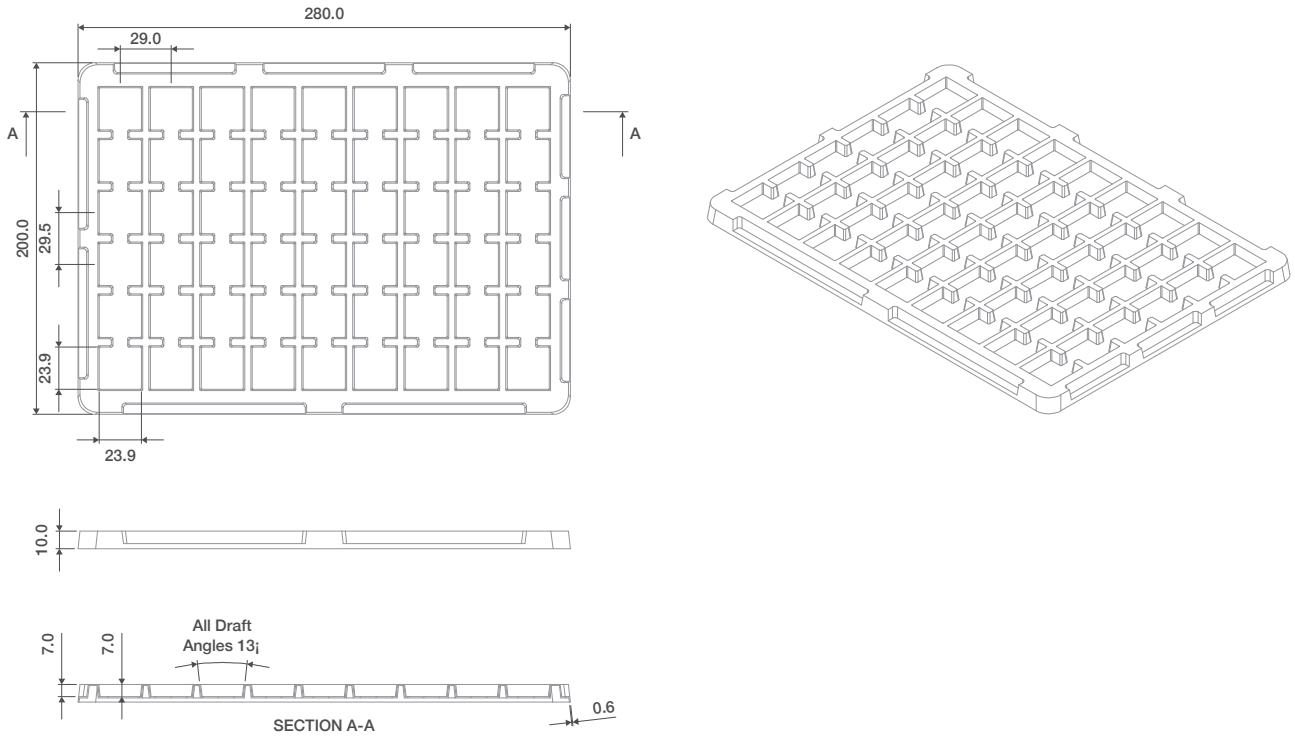**FIGURE 12-1. RED BEET REV.1.1 TRAY DIMENSIONS**

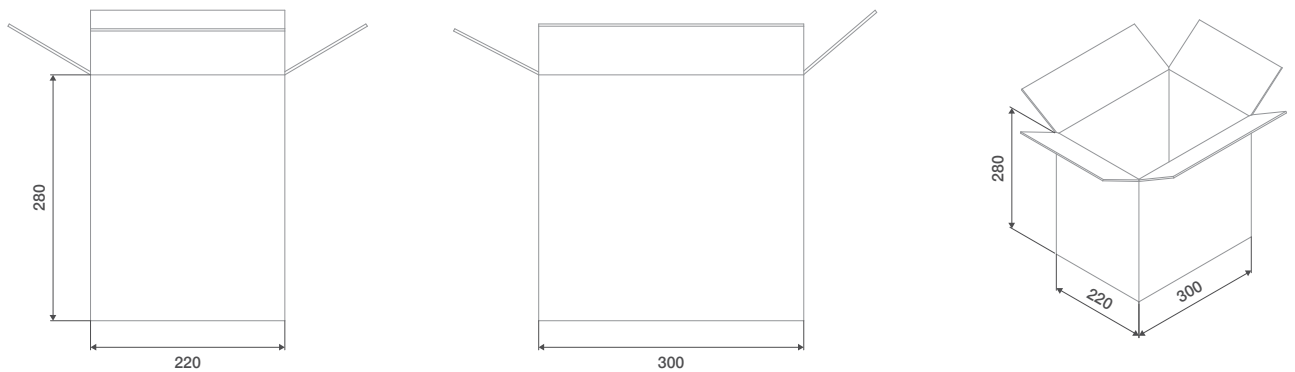**FIGURE 12-2. STANDARD PACKING BOX DIMENSIONS**

TABLE 12-1. ORDERING PART NUMBERS

Part number	Description
RED-BEET-H 1.1 #300063	RED beet rev.1.1 module for home control
RED-BEET-E 1.1 #300060	RED beet rev.1.1 module for EVSE (Electric vehicle supply equipment)
RED-BEET-P 1.1 #300062	RED beet rev.1.1 module for PEV (Plug-in electric vehicle)
CARRIER-BOARD-H #292204	Carrier board for development and testing with line coupling and SPI interface for external MCU with home control configuration
CARRIER-BOARD-E #295015	Carrier board for development and testing with line coupling and SPI interface for external MCU with EVSE configuration
CARRIER-BOARD-P #295016	Carrier board for development and testing with line coupling and SPI interface for external MCU with PEV configuration
COMM-BOARD-S #292205	Interface converter and ISO/IEC 15118-3 communication board is based on STM32F745 microcontroller for e-mobility applications with transparent or SLAC bridging software.
COMM-BOARD-I #295305	Interface converter and ISO/IEC 15118-3 communication board is based on STM32F745 microcontroller for e-mobility applications with ISO/IEC 15118 software stack.
COMM-BOARD-O #295307	Interface converter and ISO/IEC 15118-3 communication board is based on STM32F745 microcontroller for e-mobility applications with open SDK.

More PEV / EVSE - configured eMobility related products can be found in CODICO Sample Shop:

https://www.codico.com/en/products/powerline-communication

13. Product change from RED-beet to RED-beet 1.1

1. RED-BEET 1.1 module's operating temperature range changed from -40..+105°C to -40..+95°C due to TCXO replacement by XTAL with a tight tolerance.

2. Firmware upgrade to the latest Qualcomm QCA7005 FW v3.0. Backward compatible with the previous FW v1.2.5-00.

3. **RED-BEET-P 1.1 only:** onboard 0 Ohm resistor from ZC_IN input to GND removed, so ZC_IN pin 32 has to be grounded externally for PEV applications only.

4. Minor improvement of TX and RX impedance matching circuit, which causes 2dBm increase of transmit power. Module (together with reference coupling circuit) is calibrated at approximate PSD level of -73dBm/Hz, but customer's end-product design has to be re-calibrated.

14. Document revision history

Revision	Revision Date	Description
1.17	2020.12.11	Initial release as a copy of RED-beet datasheet rev.1.16 Chapter 5 and Table 12-1 (ordering information) updated Product change information added (difference between new RED-beet 1.1 and old RED-beet)