

# AN10903

## TDA5051A ASK power line modem

Rev. 1 — 17 December 2010

Application note

### Document information

| Info            | Content  |
|-----------------|--|
| <b>Keywords</b> | Home automation modem, ASK power-line modem, EN50065-1 and EN50065-2 compliant, home lighting and appliance control  |
| <b>Abstract</b> | <p>The NXP TDA5051A is a complete Amplitude Shift Keying (ASK) modem for transmitting and receiving digital signals on standard power line or any two-wire AC or DC network. It is a cost-effective solution that transmits at a rate of 600 baud (typical) and 1200 baud (maximum), operates from a single 5 V supply, and enables easy connection to standard microcontrollers, including NXP's LPC11xx series of low power ARM-based microcontrollers.</p> <p>The IC complies with EN50065-1, EN50065-2 and SC105A, and requires only a few external components for full operation. Its fully-digital transmission and reception circuitry provides efficient bidirectional communication of low baud rate data signals between a control unit and lighting fixture, and one or more household appliances connected to the mains. This application note discusses the requirements, filtering circuits and interface networks necessary to be fully compliant and to obtain robust, reliable operation in a power line communication network.</p> |



**Revision history**

| <b>Rev</b> | <b>Date</b> | <b>Description</b>                |
|------------|-------------|-----------------------------------|
| v.1        | 20101217    | application note; initial version |

**Contact information**

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: [salesaddresses@nxp.com](mailto:salesaddresses@nxp.com)

## 1. Introduction

### 1.1 TDA5051A ASK modem for power line data transmission

The TDA5051A is a complete ASK modem dedicated to data transmission on power line network, requiring very few external components. It could be also used on any two-wire network for exchanging informations by means of ASK carrier current technique (DC or AC network).

The use of a digital structure for both transmission and reception part provides an efficient solution for modulating and demodulating low baud rate data signals. A standard quartz crystal is required to set the operation frequency; in transmission mode, it defines the carrier frequency and in reception mode it defines the detection frequency.

#### 1.1.1 Main features of the IC

- **CMOS process IC:** low power consumption, reliability and high temperature stability, on-chip ESD protection
- **Single +5 V power supply.** The same power supply can be used to feed the controller.
- **On-chip clock circuit.** Using an external quartz crystal, the oscillator sets the operation frequency and the clock output pin gives the possibility to supply the clock to a microcontroller. It is also possible to apply an external clock signal to the chip by using one of the oscillator pins as an input.
- **Full digital modulation with signal shaping.** Using ROM and a 6-bit D/A converter provides high stability of the carrier frequency, limitation of the signal bandwidth and easy choice of the frequency within a large range.
- **On-chip power amplifier with overload protection.** Low distortion, low output impedance amplifier for limiting the number of external components and the size of the complete system. An internal feedback controls the output voltage to comply with the EN50065-1 standard (122 dB $\mu$ V maximum (RMS)).
- **Input amplifier with Automatic Gain Control (AGC).** Provides a very high sensitivity of 66 dB $\mu$ V (RMS), allowing the detection of small signals in heavily loaded power line conditions.
- **Digital narrowband filter with 8-bit A/D converter.** Equivalent to an 8<sup>th</sup>-order analog filter, for an accurate and sharp filtering of the input signal.
- **Digital demodulation.** A digital demodulator with variable threshold calculates the optimum level in order to restore the baseband signal with the highest accuracy.
- **600 baud typical rate, 1200 baud maximum**
- **TTL/CMOS compatible data pins** for direct connection to the controller.
- **Digital part fully scan testable** for a complete digital production check, before and after packaging of the IC.
- **Low cost external coupling network** using a simple LC filter without any tunable components.

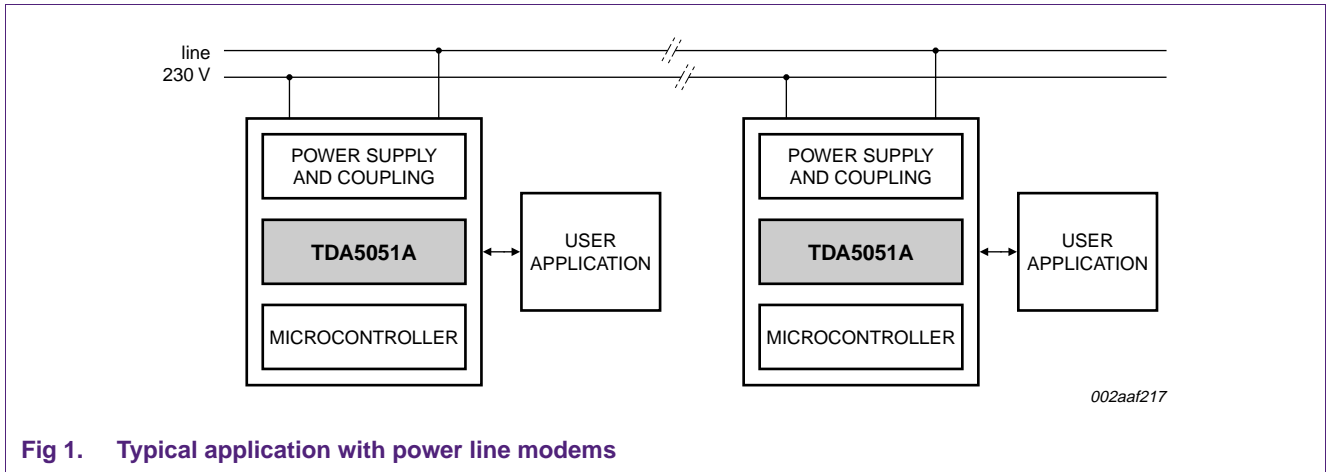


Fig 1. Typical application with power line modems

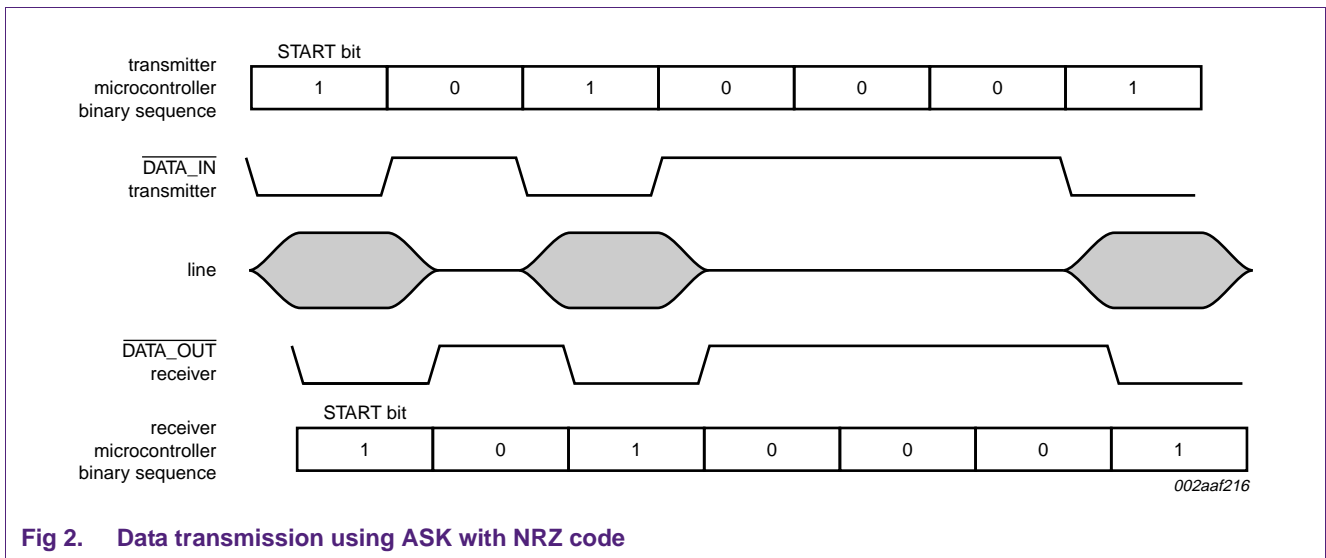


Fig 2. Data transmission using ASK with NRZ code

1.2 Block diagram

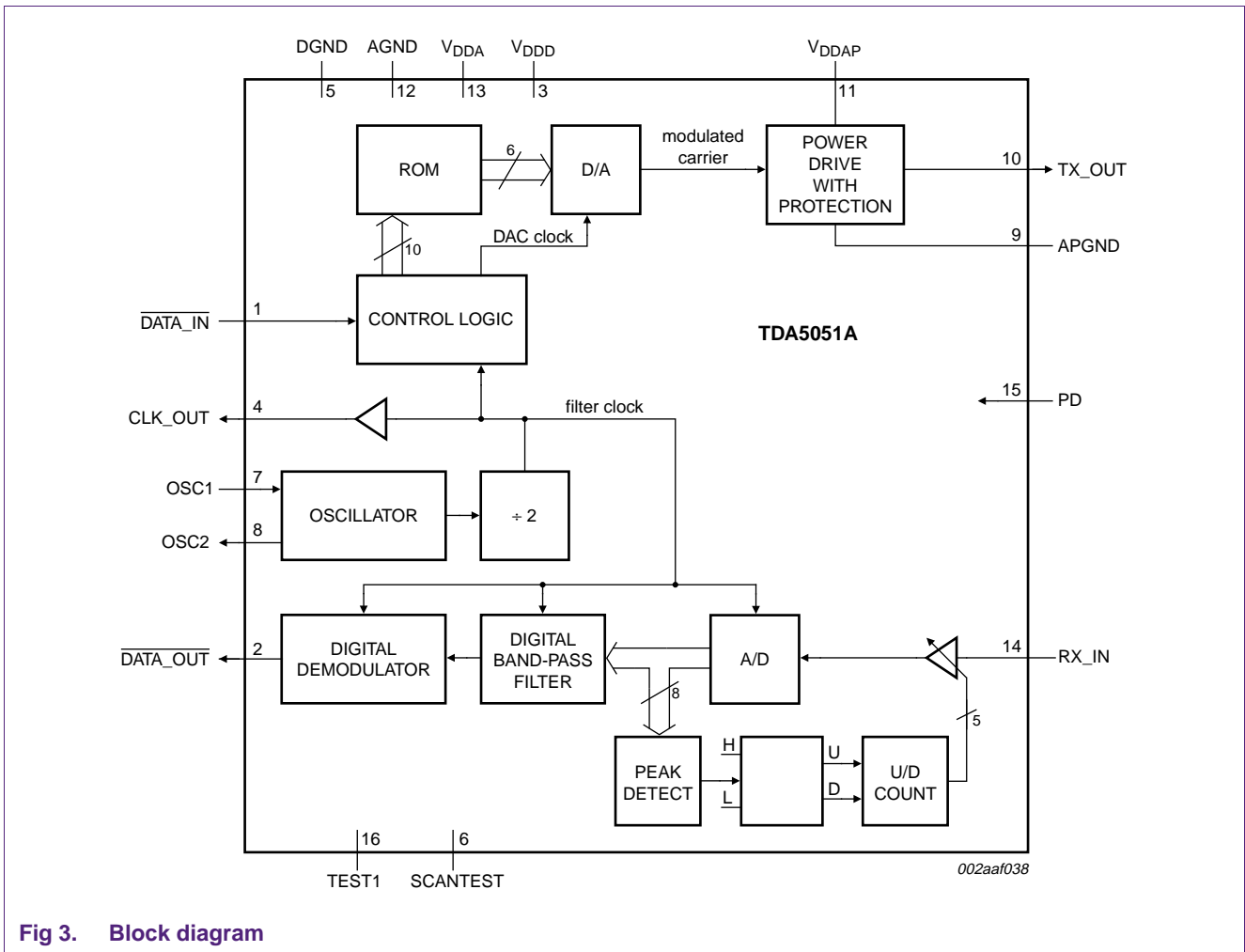


Fig 3. Block diagram

### 1.3 Pinning

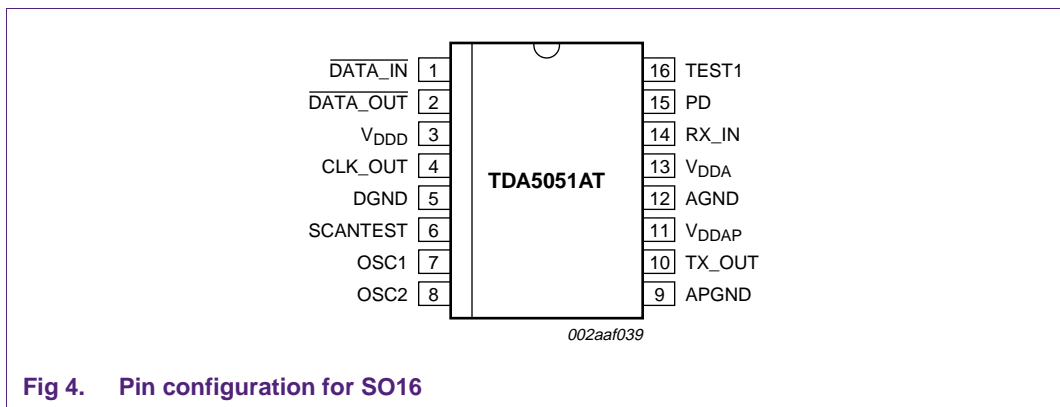


Fig 4. Pin configuration for SO16

Table 1. Pin description

| Symbol            | Pin | Description   |
|-------------------|-----|---|
| DATA_IN           | 1   | digital data input (active LOW)                             |
| DATA_OUT          | 2   | digital data output (active LOW)                            |
| V <sub>DD</sub>   | 3   | digital supply voltage                                      |
| CLK_OUT           | 4   | clock output  |
| DGND              | 5   | digital ground  |
| SCANTEST          | 6   | test input (LOW in application); on-chip pull-down resistor |
| OSC1              | 7   | oscillator input  |
| OSC2              | 8   | oscillator output   |
| APGND             | 9   | analog ground for power amplifier                           |
| TX_OUT            | 10  | analog signal output  |
| V <sub>DDAP</sub> | 11  | analog supply voltage for power amplifier                   |
| AGND              | 12  | analog ground   |
| V <sub>DDA</sub>  | 13  | analog supply voltage                                       |
| RX_IN             | 14  | analog signal input   |
| PD                | 15  | power-down input (active HIGH); on-chip pull-down resistor  |
| TEST1             | 16  | test input (HIGH in application); on-chip pull-up resistor  |

## 2. Compliance with standards

### 2.1 Compliance with EN50065-1

(Main points only; please refer to the norm for further details.)

#### 2.1.1 Choice of the carrier frequency

The operating frequency of the modem is only defined by the choice of the quartz crystal or by the frequency of the signal applied at the oscillator input, as shown in [Table 2](#).

**Table 2. Carrier frequency**

| Oscillator frequency | Clock output frequency | Carrier and detection frequency |
|----------------------|------------------------|---------------------------------|
| $f_{osc}$            | $f_{osc} / 2$          | $f_{osc} / 64$                  |

However, to comply with the EN50065-1 norm, the carrier frequency for power line data transmission must be chosen within the following range:

**Table 3. Power line data transmission carrier frequency**

| 9 kHz to 95 kHz | 95 kHz to 125 kHz  | 125 kHz to 140 kHz  | 140 kHz to 148.5 kHz |
|-----------------|--------------------|---|----------------------|
| restricted use  | free for consumers | free for consumers  | free for consumers   |
| -               | no access protocol | requested protocol:<br>use 132.5 kHz to inform<br>that a transmission is in<br>progress | no access protocol   |

In order to avoid problems with the bandwidth of the modulated signal, it would be better to choose a carrier frequency (which is in fact a 'center frequency') higher than 95 kHz and lower than 148.5 kHz; for example 98 kHz to 145.5 kHz is a good compromise.

Then, the oscillator frequency range is 64 times higher than these two values, which gives 6.272 MHz to 9.312 MHz. For the special frequency of 132.5 kHz, a crystal of 8.48 MHz should be used.

For instance, using commercial quartz crystals gives the set of carrier frequencies shown in [Table 4](#).

**Table 4. Carrier frequency choice**

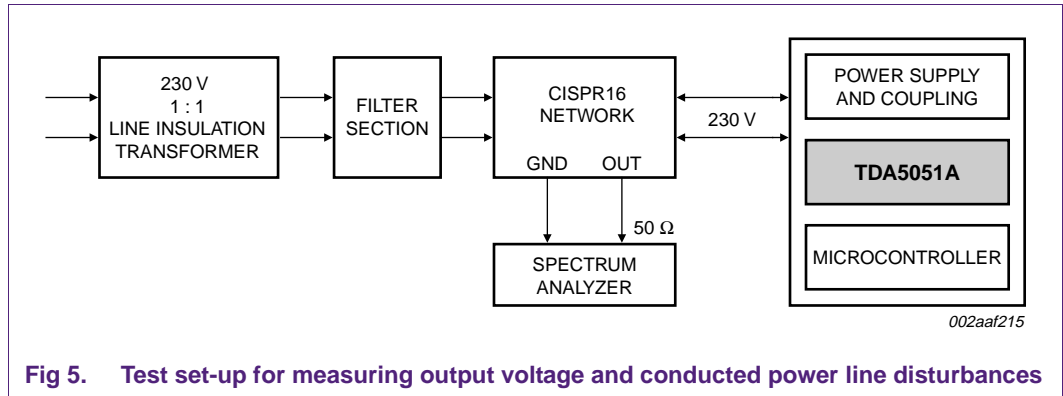
| $f_{osc}$ (MHz); XTAL   | $f_{CLK\_OUT}$ (MHz); CLK_OUT pin | $f_c$ (kHz); carrier (center) |
|-------------------------|-----------------------------------|-------------------------------|
| 6.553600                | 3.27680                           | 102.4                         |
| 7.372800                | 3.68640                           | 115.2                         |
| 7.864320                | 3.93216                           | 122.88                        |
| 8.000000                | 4.00000                           | 125.00                        |
| 8.192000                | 4.09600                           | 128.00                        |
| 8.480000 <sup>[1]</sup> | 4.24000                           | 132.50                        |
| 8.867230                | 4.43361                           | 138.55                        |

[1] Note that 8.48 MHz is still not a standard frequency.

**2.1.2 Modem output voltage**

The maximum output voltage of a power line modem is also defined by the norm, and the measurement of this voltage must be performed as described in the EN50065-1.

Basically, it consists of measuring, with a 50 Ω spectrum analyzer, the carrier amplitude of the complete system (modem + coupling network) on a standard load, called the CISPR16 load.



**Fig 5. Test set-up for measuring output voltage and conducted power line disturbances**

The CISPR16 Network provides an attenuation of 6 dB, due to its structure. The maximum RMS voltage measured on the analyzer must be in the range given in [Table 5](#).

**Table 5. Maximum RMS voltage range**

| Domestic use only                               | Industrial or specific use                      |
|---|---|
| maximum 116 dBμV with CISPR16 network           | maximum 134 dBμV with CISPR16                   |
| effective value at the modem output is 122 dBμV | effective value at the modem output is 140 dBμV |
| 3.56 V peak-to-peak                             | 28.3 V peak-to-peak                             |

The internal power amplifier of the TDA5051A is designed to supply the voltage required for domestic applications. For a higher voltage value, an extra power amplifier should be used.

**2.1.3 Limiting conducted power line disturbances**

One of the most important points of the EN50065-1 standard concerns the amplitude limitation of non-expected harmonics outside the transmission band. To be officially approved, this test requires specific equipment, but a measurement with a CISPR16 network and a 50 Ω analyzer (resolution bandwidth of 9 kHz) can give a good idea of the conducted disturbances.

The peak value of these harmonics must be within the limits given in [Table 6](#).

**Table 6. Amplitude limitation of non-expected harmonics outside transmission band**

| Frequency range (MHz) | Peak limit (dBμV)  |
|-----------------------|--|
| 0.15 to 0.5           | 66 to 56; decreasing linearity with the log of frequency |
| 0.5 to 5              | 56   |
| 5 to 30               | 60   |



## 2.2 Compliance with EN50065-2 (project stage)

### 2.2.1 Immunity requirements: narrowband conducted interferences

This is another important point of specification for power line modems, which is closely tied to the application.

The EN50065-2 (SC105A) norm defines the operation conditions of two systems (emitter and receiver) connected to an artificial network, with a given level of conducted interference signal.

This signal, for the narrowband test, is an 80 % 1 kHz modulated sine wave, supplied by a signal generator as shown in [Figure 6](#).

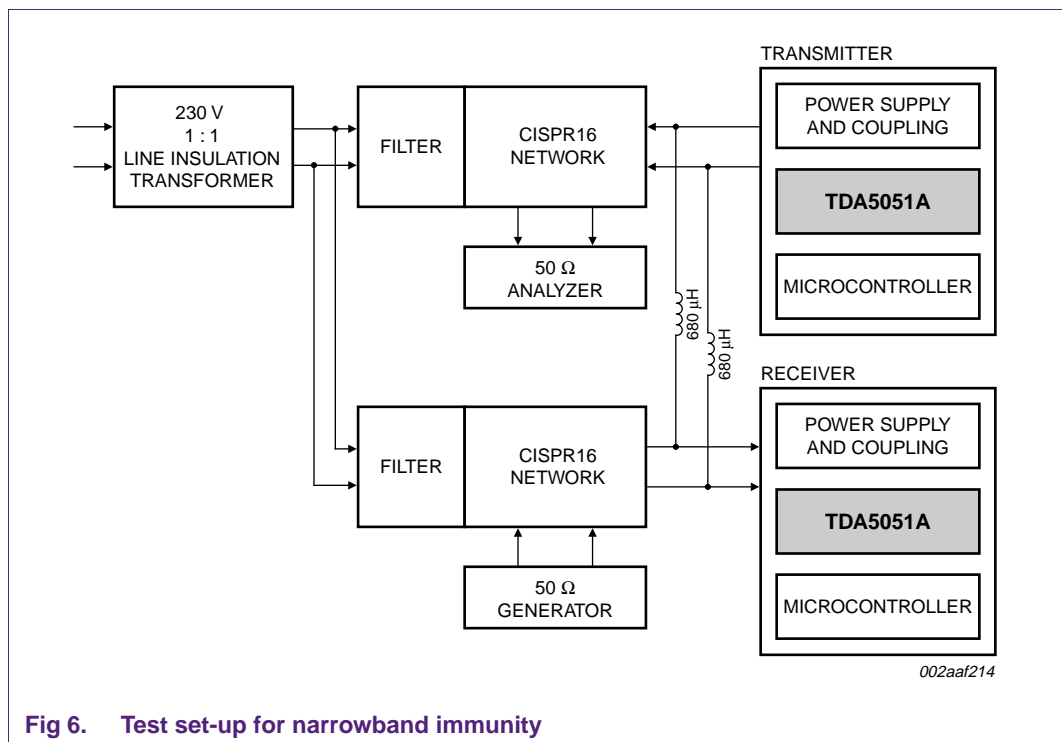


Fig 6. Test set-up for narrowband immunity

Then this interference signal is swept through a wide frequency range from 3 kHz to 30 MHz, excluding the band defined in [Table 3](#), in which the system operates. The interference signal must have the amplitude (measured unmodulated at the output of the generator) given in [Table 7](#).

Table 7. Interference signal amplitude

| Frequency range      | Interference signal amplitude    | Performance criterion of the complete system               |
|----------------------|----------------------------------|--|
| 3 kHz to 8 kHz       | 134 dB $\mu$ V                   | system will continue to operate correctly                  |
| 10 kHz to 94 kHz     | 134 dB $\mu$ V to 120 dB $\mu$ V | system will continue to operate correctly                  |
| 96 kHz to 124 kHz    | 134 dB $\mu$ V                   | self-recoverable temporary loss of function or performance |
| 126 kHz to 139 kHz   | 134 dB $\mu$ V                   | self-recoverable temporary loss of function or performance |
| 141 kHz to 147.5 kHz | 134 dB $\mu$ V                   | self-recoverable temporary loss of function or performance |
| 150 kHz to 30 MHz    | 130 dB $\mu$ V                   | self-recoverable temporary loss of function or performance |

The behavior of the system during this test is not only dependant on the modem performances. The implemented software of the application and the protocol may be decisive to successfully do this test.

However, these elementary rules should be used for designing the system:

1. Avoid the edges of the allowed bands by choosing a 'centered' carrier frequency.
2. Design the external filter (see [Section 3](#)) for high rejection of unexpected frequencies.
3. Implement a software able to perform multi-sampling on the received data signal.
4. Avoid 'open loop' control; preferably use an 'acknowledge based' protocol.
5. If possible, use binary codes with error correction capabilities.

The structure of the TDA5051A has been designed to cope with severe test conditions by using very efficient digital filtering and a variable threshold demodulator. However, under certain operating conditions, correct detection is not guaranteed.

### 2.2.2 Immunity requirements: broadband noise interferences

For this test, the generator shown in [Figure 6](#) is replaced by a random noise generator producing a uniform spectrum from 3 kHz to 150 kHz, having a spectral density of 43 dB $\mu$ V / square root (Hz).

The system must operate correctly under these conditions.

The rules [3](#), [4](#) and [5](#) given in [Section 2.2.1](#) are still valid.

### 2.2.3 Input impedance of the power line equipment

In order to allow the coexistence of several power line modems on the same network, a minimum value of the input impedance has been proposed by the SC105A standard.

That means, a guaranteed minimum input impedance for the coupling network (external filter) but also for the power supply. These aspects are mentioned in the filter design section ([Section 3.2.1](#)) and in [Section 5 "Power supply design"](#).

This value has been set to 5  $\Omega$ , in the frequency range of 95 kHz to 148.5 kHz.

### 3. Coupling with the power line

#### 3.1 Introduction

The coupling network is the interface between the power line and the low voltage TX\_OUT and RX\_IN pins of the modem. For low cost applications, when the insulation with the mains is not required, a double LC network can be used, providing efficiency without any adjustment or tunable components. When an insulation is mandatory, an HF transformer should be used.

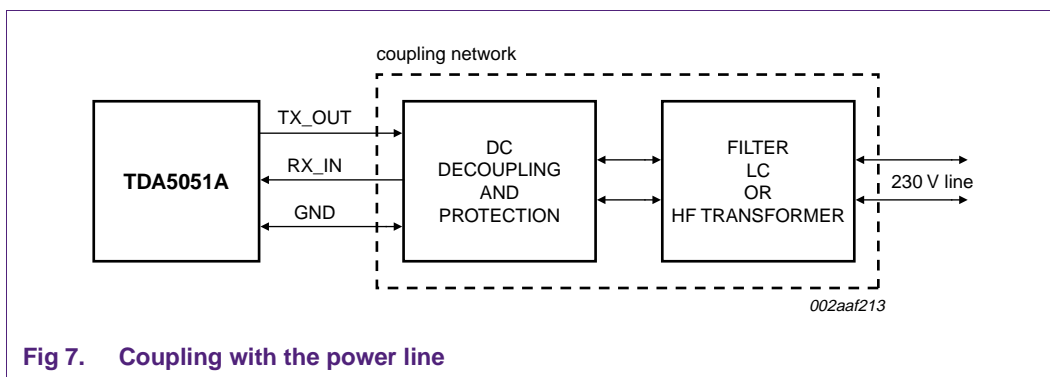


Fig 7. Coupling with the power line

#### 3.1.1 Decoupling TX\_OUT and RX\_IN pins

Table 8 shows the electrical characteristics of TX\_OUT and RX\_IN pins in different operation modes.

Table 8. TX\_OUT and RX\_IN pin characteristics

| Characteristic    | Reception/Standby mode | Transmission mode | Power-down mode |
|-------------------|------------------------|-------------------|-----------------|
| <b>TX_OUT pin</b> |                        |                   |                 |
| impedance         | HIGH                   | approximately 5 Ω | HIGH            |
| DC offset         | undefined              | 2.5 V             | undefined       |
| <b>RX_IN pin</b>  |                        |                   |                 |
| impedance         | 50 kΩ                  | 50 kΩ             | 50 kΩ           |
| DC offset         | 2.5 V                  | 2.5 V             | 2.5 V           |

**Remark:** It is mandatory to provide a DC decoupling for both TX\_OUT and RX\_IN pins.

It is not possible to tie together TX\_OUT and RX\_IN, even if the DC offset is the same. The RX\_IN pin is very sensitive to a small shift of the DC voltage, which is internally set to bias the input amplifier at an optimum level.

#### 3.1.2 Filter

The filter has two purposes:

- **In reception mode:** It provides an efficient rejection of the 50 Hz signal (high-pass) and anti-aliasing (low-pass) for the digital filter. It is important to keep in mind that the digital filter is able to detect the  $f_c$  component of the carrier, but also the  $\pm f_c$  components located around the sampling frequency ( $f_{osc} / 2$ ) and its multiples.

For instance, the 50 Hz amplitude is 230 V (RMS) or 167 dB $\mu$ V, and the maximum sensitivity of the modem is 66 dB $\mu$ V; to take advantage of the detection performance, the filter must reject the 50 Hz of more than 100 dB, which means an efficiency higher than 30 dB / decade.

For the anti-aliasing rejection around the sampling frequency, 50 dB seems to be a good compromise.

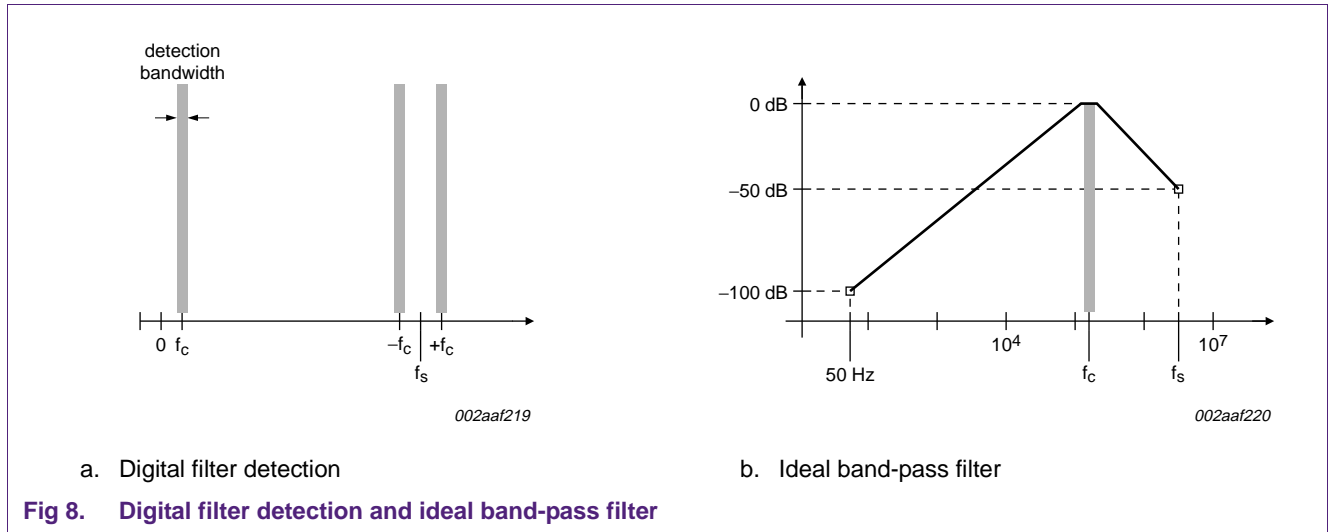


Fig 8. Digital filter detection and ideal band-pass filter

- In transmission mode:** It provides a rejection of unexpected harmonics in order to comply with the EN50065-1 standard. The carrier being synthesized by scanning a ROM, its spectrum is repeated around the sampling frequency ( $f_{OSC} / 2$ ) and its multiples ( $f_{OSC}$ ,  $3 \times f_{OSC} / 2$ ,  $2 \times f_{OSC}$ , etc.), with decreasing amplitude.

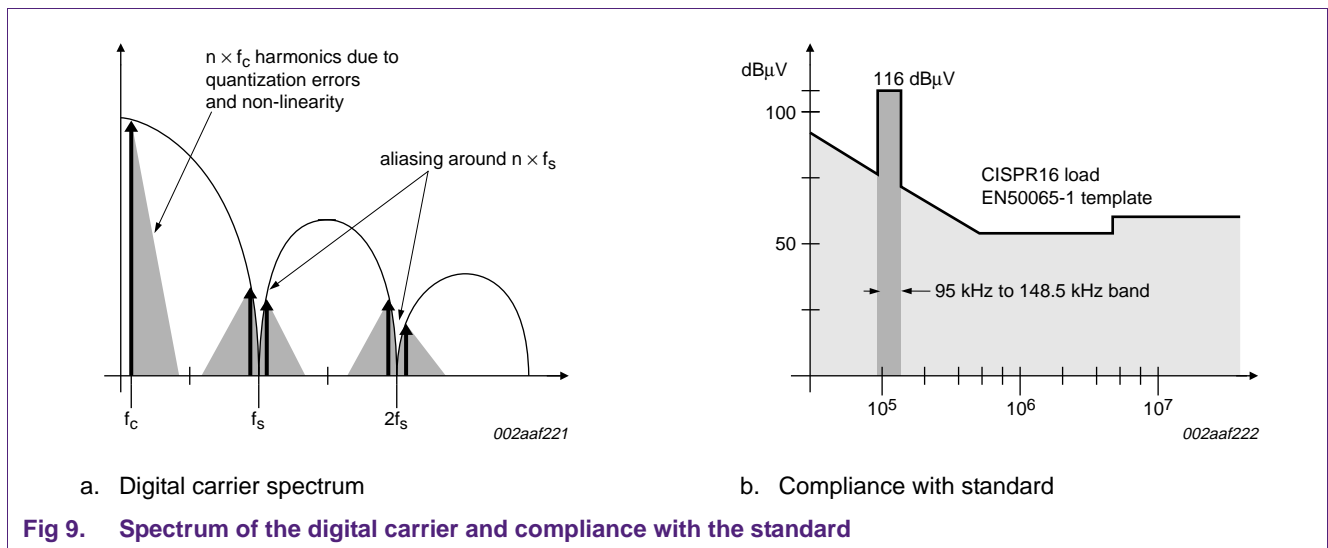


Fig 9. Spectrum of the digital carrier and compliance with the standard

### 3.2 Low cost coupling

#### 3.2.1 Introduction

This coupling uses a double LC band-pass filter. It does not provide any insulation from power line.

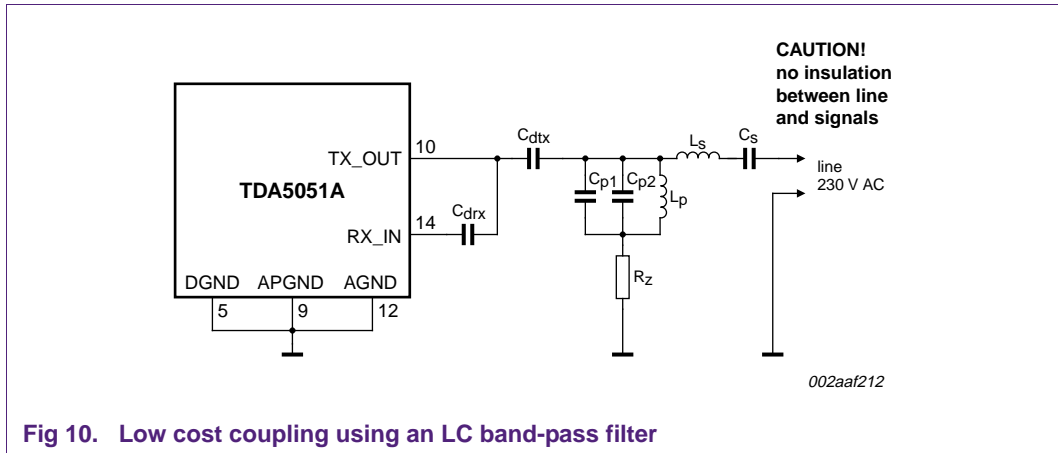


Fig 10. Low cost coupling using an LC band-pass filter

##### 3.2.1.1 DC decoupling of TX\_OUT and RX\_IN

The values of  $C_{dtx}$  and  $C_{drx}$  are not critical.

$C_{dtx}$  must be chosen to provide a low-impedance at the carrier frequency (less than  $1 \Omega$  for instance). [Table 9](#) shows the recommended values for these capacitors.

Table 9. Recommended values for  $C_{drx}$  and  $C_{dtx}$  capacitors

| Capacitor | Recommended value                                  |
|-----------|--|
| $C_{dtx}$ | 1 $\mu$ F to 10 $\mu$ F non-polarized electrolytic |
| $C_{drx}$ | 1 nF to 10 nF ceramic or plastic                   |

##### 3.2.1.2 Design of the LC filter

The LC filter must be tuned for the chosen carrier frequency. One can use the simple formula in [Equation 1](#):

$$f_c = \frac{1}{2\pi \times \sqrt{L_s \times C_s}} = \frac{1}{2\pi \times \sqrt{L_p \times (C_{p1} + C_{p2})}} = \frac{f_{osc}}{64} \tag{1}$$

with  $f_c$  and  $f_{osc}$  in Hertz, L in Henry, and C in Farad.

Apart from rejection characteristics mentioned above, the other features of this network should be:

Minimum impedance in transmission for the  $L_s$ - $C_s$  part of the filter: that means a low serial resistor for  $L_s$  and good tuning at the carrier frequency. That also means a good balance between the values of  $L_s$  and  $C_s$  for the same tuning frequency, taking into account the possible variation of standard components ( $\pm 20\%$  for high voltage capacitors,  $\pm 10\%$  or  $\pm 5\%$  for inductors).

Minimum input impedance of the filter: if required, the  $R_z$  resistor (see [Figure 10](#)) can be chosen from  $0 \Omega$  to  $5.6 \Omega$ , in order to limit the minimum input impedance of the filter (EN standard is at a project stage about this point).

**Remark:** One must take into account that a too high value for  $R_z$  may affect the rejection of HF harmonics in transmission. (The best rejection is carried out with  $R_z = 0 \Omega$ .)

[Table 10](#) shows an example of values for the filter components, according to standard quartz crystals.

**Remark:** Depending on the complete application of the customer (power supply, routing of the board, placement, etc.), the compliance with EN50065-1 is not guaranteed, and must be checked anyway.

**Table 10. Values of  $L_s$ ,  $L_p$ ,  $C_{p1}$ ,  $C_{p2}$ ,  $C_s$  and XTAL for different carrier frequencies**

| $f_{osc}$ XTAL (MHz)    | $f_{CLK\_OUT}$ (MHz) | $f_c$ carrier (kHz) | $L_s$ (low $R_s$ ) ( $\mu$ H) | $C_s$ <sup>[3]</sup> (250 V AC) (nF) | $L_p$ ( $\mu$ H) | $C_{p1}$ (nF) | $C_{p2}$ (nF) |
|-------------------------|----------------------|---------------------|-------------------------------|--------------------------------------|------------------|---------------|---------------|
| 6.553600 <sup>[1]</sup> | 3.27680              | 102.4               | 56                            | 47                                   | 47               | 47            | 4.7           |
| 7.372800 <sup>[1]</sup> | 3.68640              | 115.2               | 47                            | 47                                   | 47               | 33            | 6.8           |
| 7.864320 <sup>[1]</sup> | 3.93216              | 122.88              | 47                            | 33                                   | 47               | 33            | 2.2           |
| 8.000000 <sup>[1]</sup> | 4.00000              | 125.00              | 47                            | 33                                   | 47               | 33            | -             |
| 8.192000 <sup>[1]</sup> | 4.09600              | 128.00              | 47                            | 33                                   | 47               | 33            | -             |
| 8.480000 <sup>[2]</sup> | 4.24000              | 132.50              | 47                            | 33                                   | 47               | 27            | 3.3           |
| 8.867230 <sup>[1]</sup> | 4.43361              | 138.55              | 56                            | 22                                   | 47               | 27            | -             |

[1] XTAL are standard HC49 quartz crystals; each carrier frequency belongs to the EN50065-1 transmission board.

[2] 8.48 MHz is still not a standard frequency.

[3]  $C_s$  must be an X2 type capacitor, suited for 250 V AC line voltage;  $L_s$  is preferably a low  $R_s$  inductor.

### 3.2.2 Design example of a typical coupling network

Designer choices:

- Frequency band: no protocol used, so the 95 kHz to 125 kHz band is chosen.
- Carrier frequency: within this frequency range, a standard quartz crystal of 7.3728 MHz gives a carrier of 115.2 kHz.
- The components should be:  $L_s = 47 \mu\text{H} \pm 10\%$  with  $R_s = 2 \Omega$ ,  $C_s = 47 \text{ nF} \pm 20\%$  X2 (suited for 230 V AC),  $L_p = 47 \mu\text{H} \pm 10\%$  with  $R_s = 5 \Omega$  SMD inductor,  $C_{p1} = 33 \text{ nF}$  25 V SMD,  $C_{p2} = 6.8 \text{ nF}$  SMD,  $R_z = 5.6 \Omega$ .
- The decoupling  $C_{dtx}$  is a  $10 \mu\text{F} / 16 \text{ V}$  non-polarized capacitor;  $C_{dtx}$  is a  $10 \text{ nF}$  25 V SMD capacitor.

With this filter, one can simulate the reception transfer characteristics, the input impedance and the transmission transfer characteristics on the standard load. It is also possible to simulate the losses in transmission on different resistive loads.

The last check for a coupling network consists of carrying out a spectrum measurement with a CISPR16 load; a real example is given at the end of this chapter.

3.2.2.1 Reception mode — transfer characteristic of the LC filter

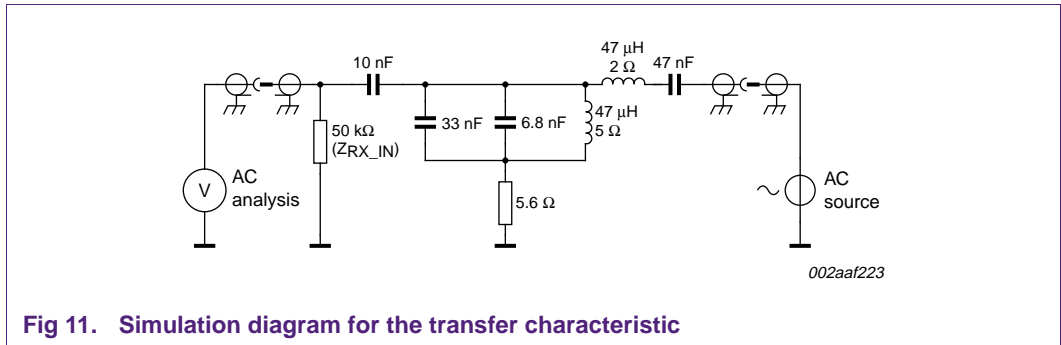


Fig 11. Simulation diagram for the transfer characteristic

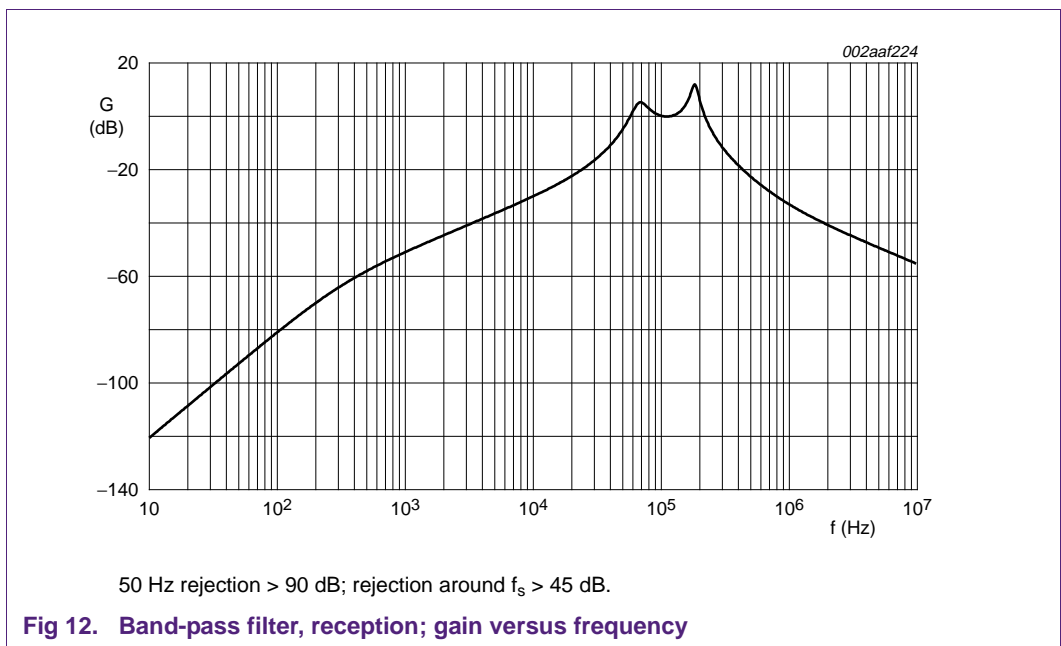


Fig 12. Band-pass filter, reception; gain versus frequency

3.2.2.2 Reception mode — input impedance of the LC filter

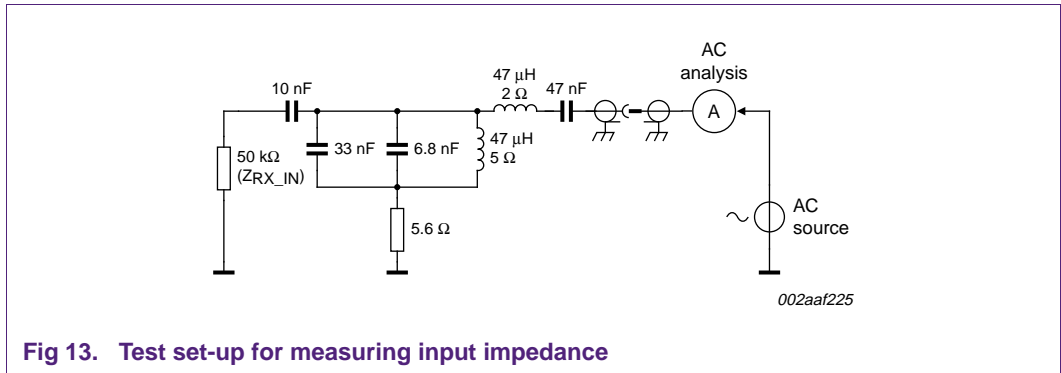


Fig 13. Test set-up for measuring input impedance

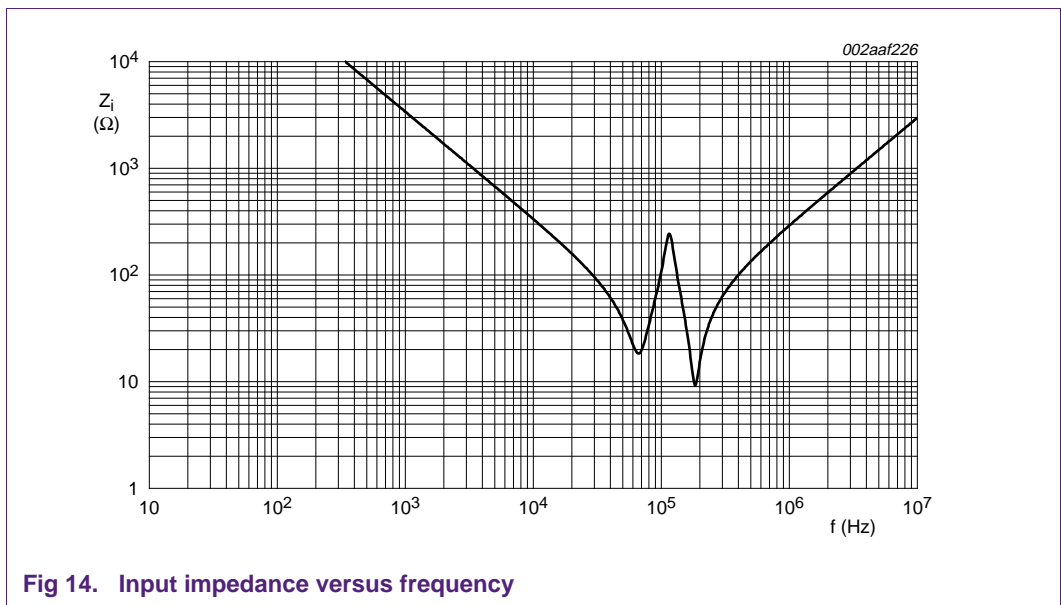


Fig 14. Input impedance versus frequency



3.2.2.3 Transmission mode — transfer characteristic of the LC filter with a CISPR16 load

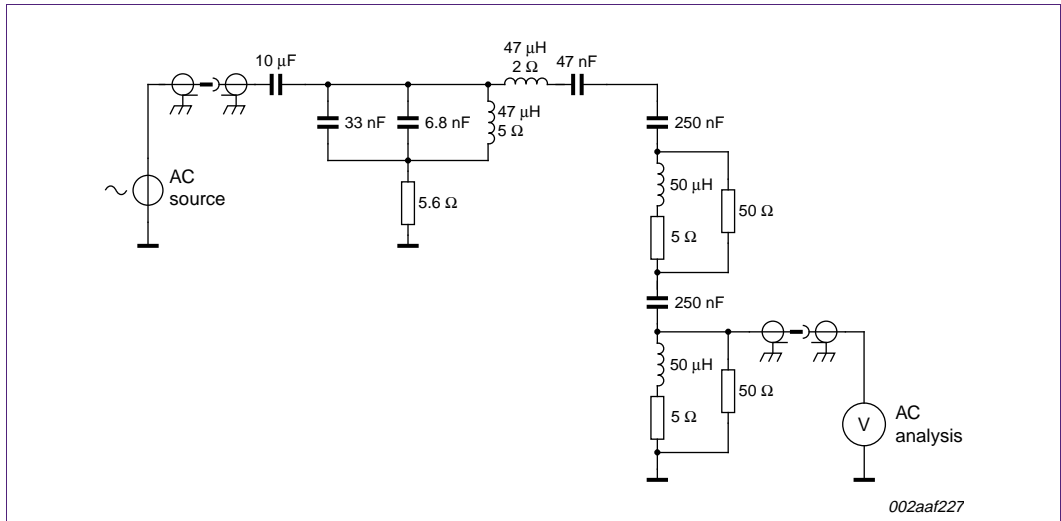
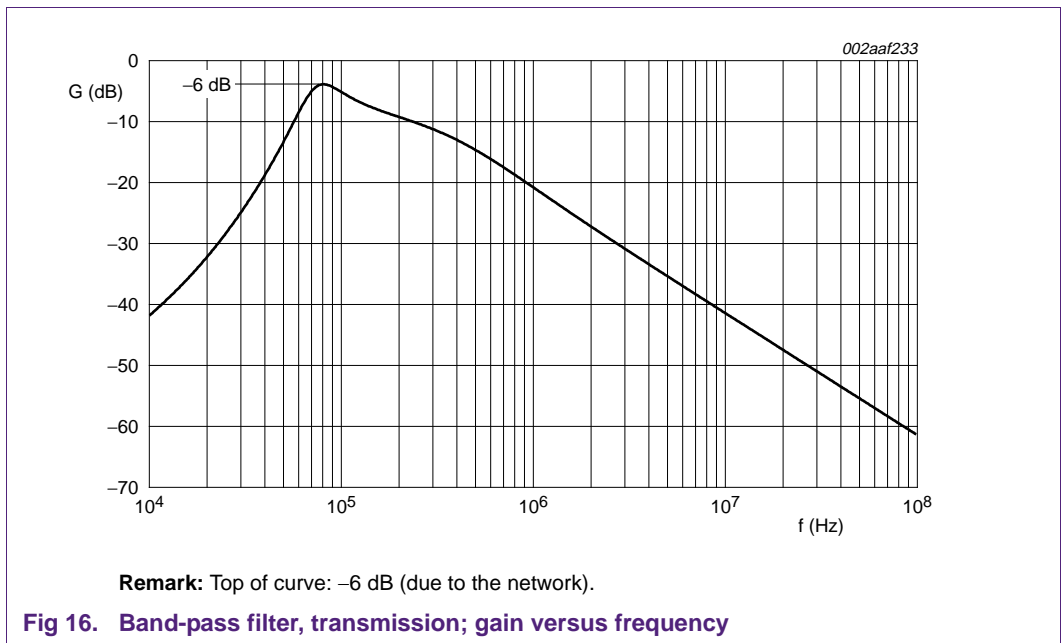


Fig 15. Measurement set-up; transfer characteristic in transmission on CISPR16 load



Remark: Top of curve: -6 dB (due to the network).

Fig 16. Band-pass filter, transmission; gain versus frequency

3.2.2.4 Transmission mode — efficiency of the LC filter

It could be useful to simulate the efficiency of the coupling for different loads and for different marginal conditions in the values of  $C_s$  and  $L_s$ . For this simulation, a fixed frequency and voltage generator is used with a serial resistor of  $5\ \Omega$ , to represent the output amplifier.

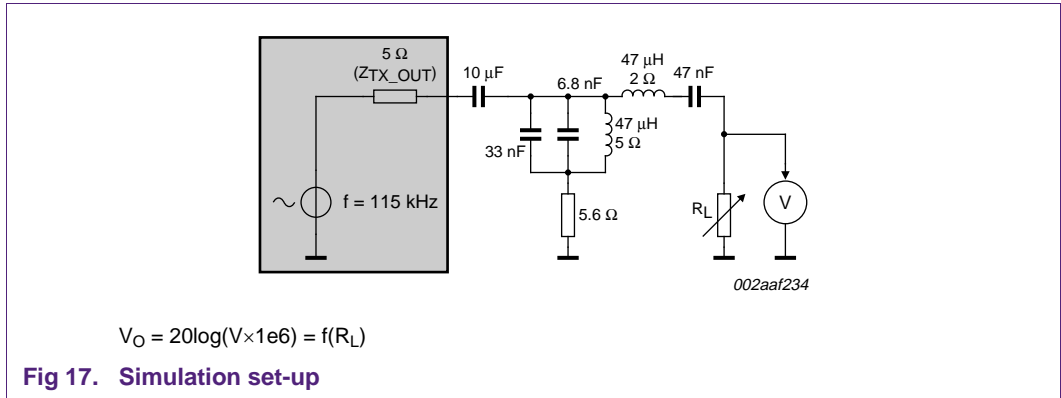


Figure 18 shows the coupling efficiency on a resistive load, with optimum values for  $C_s = 47\ nF$  and  $L_s = 47\ \mu H$ ; the maximum RMS level is  $122\ dB_{\mu V}$  and the minimum is  $103\ dB_{\mu V}$ , for  $1\ \Omega$  load.

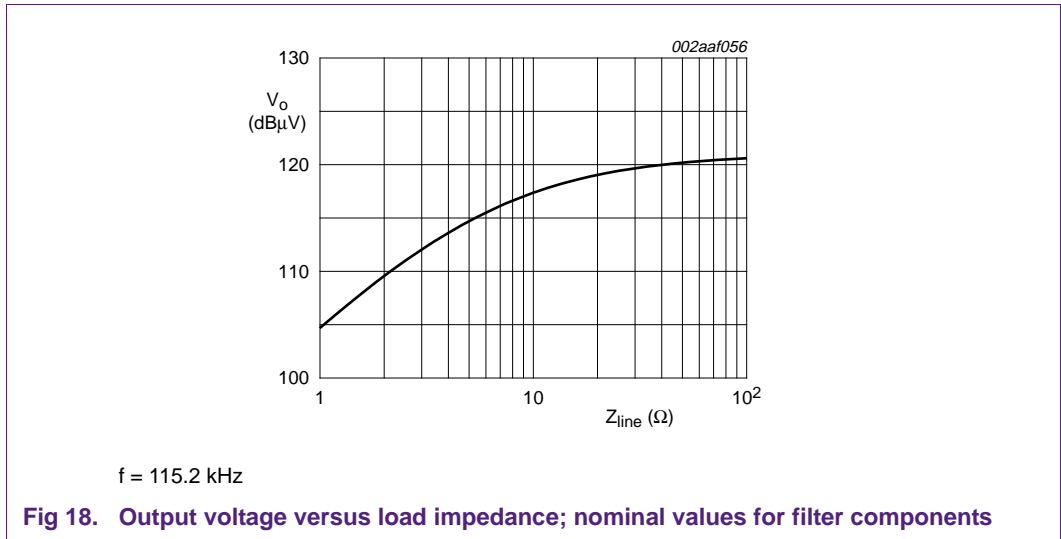
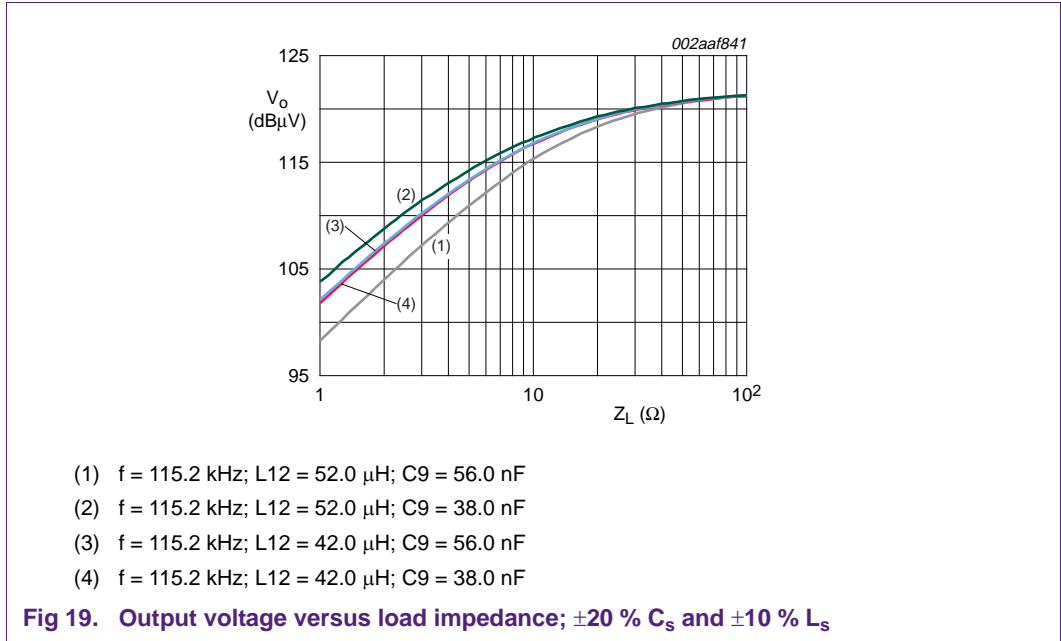
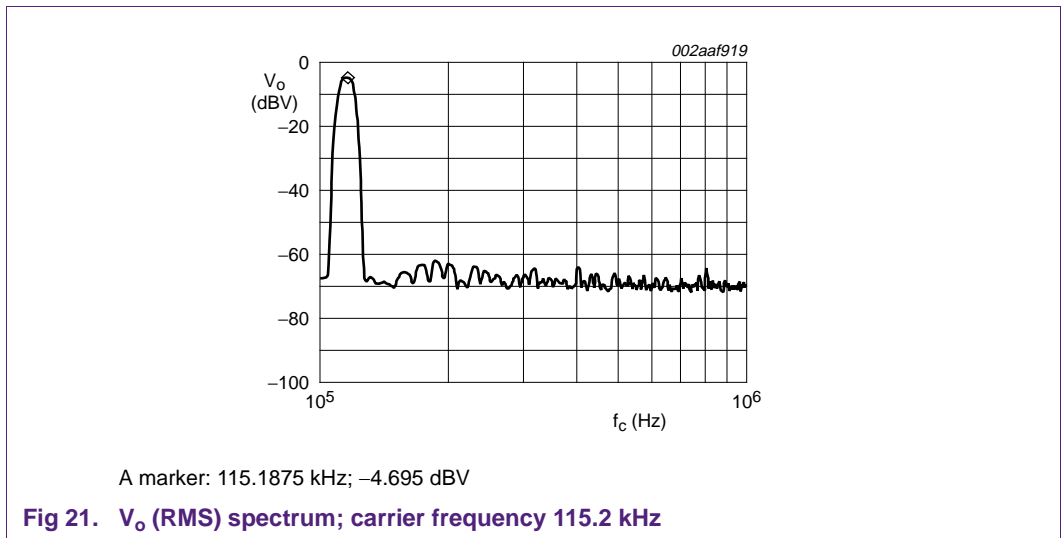
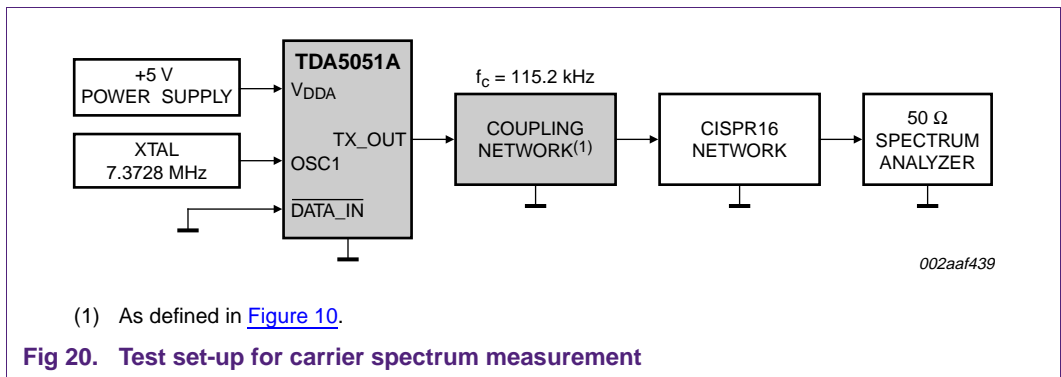


Figure 19 shows marginal conditions, with  $C_s = 47\ nF \pm 20\ %$  and  $L_s = 47\ \mu H \pm 10\ %$  (4 plots). In the worst case ( $47\ nF + 20\ %$ ,  $47\ \mu H + 10\ %$ ), the output voltage is still higher than  $98\ dB_{\mu V}$  for the maximum load. The variation of  $C_p$  and  $L_p$  has no significant effect on the efficiency.



**3.2.2.5 Transmission mode — spectrum of the carrier signal with low cost coupling network**

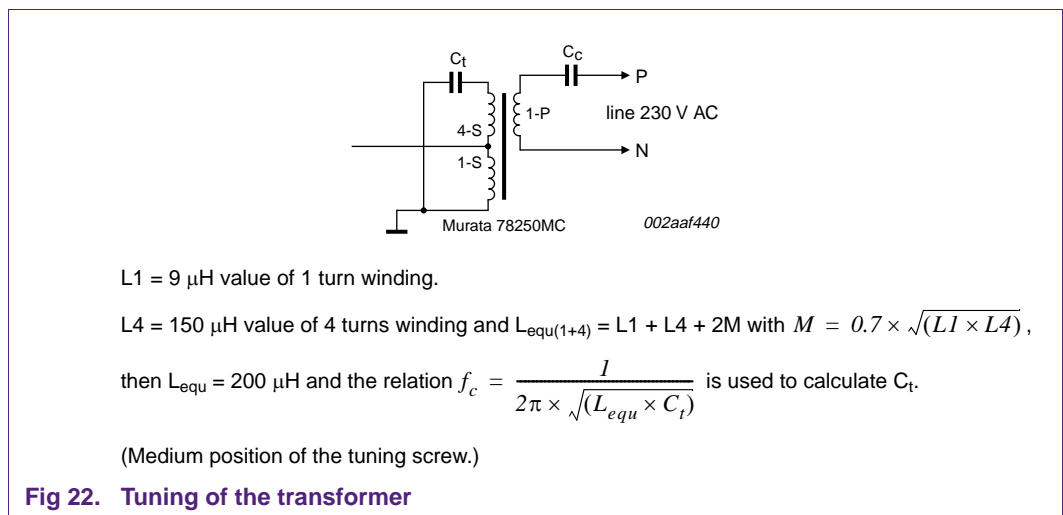


### 3.3 Coupling with HF transformer

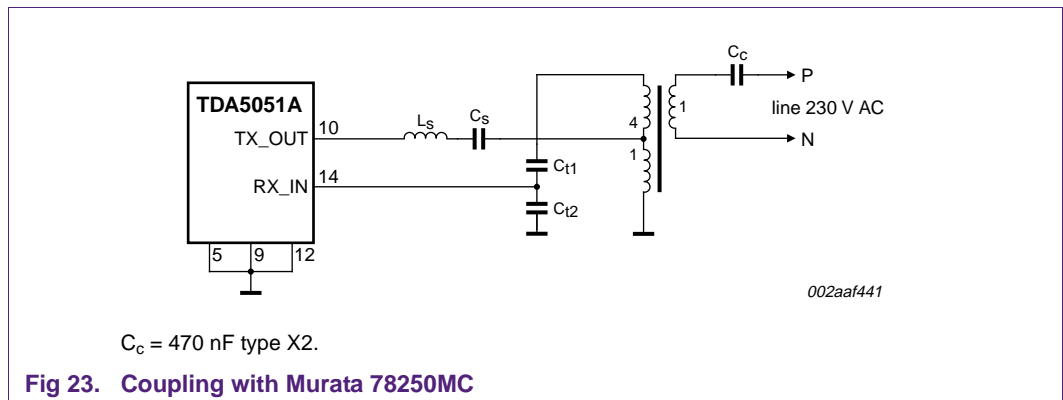
#### 3.3.1 Introduction

If the application requires insulation between the modem and the power line, it is mandatory to use a small signal transformer. Apart from the insulation with the power line, the transformer also has to realize the appropriate filtering, both in transmission and reception. The Murata 78250MC can be used for this application; it has a primary and two secondary winding, one of them having a ratio of 4 : 1.

To operate correctly, the transformer has to be tuned (with the tuning screw) to the carrier frequency, and requires an external capacitor  $C_t$ , which can be placed on the serial connection of the two secondary windings, as shown in [Figure 22](#).



The value of  $C_t$  can be easily calculated for a given carrier frequency  $f_c$ . Then, the  $C_c$  capacitor is used to couple with the power line and must be an X2 type, rated for mains voltage.



To provide efficient transmission coupling, the 1 : 1 secondary winding can be used, but needs an extra LC serial filter in order to comply with standards. In fact, the behavior of the 1 : 1 winding is mainly a high-pass filter, and does not provide efficient filtering of high frequency harmonics.

In Reception mode, the (4 : 1 + 1 : 1) secondary windings, fitted with the tuning capacitor, provides a very efficient band-pass filter, with high rejection of 50 Hz and anti-aliasing capabilities. The only problem is the ratio of 5 : 1 of the complete secondary winding, which may apply to the reception input a voltage 5 times higher than expected.

A solution is to use a capacitor divider, providing an equivalent value of  $C_t$  and a voltage ratio of 1 / 5. The complete diagram is given in [Figure 23](#).

The values of  $C_{t1}$ ,  $C_{t2}$ ,  $C_s$  and  $L_s$  must be calculated with [Equation 2](#):

$$f_c = \frac{1}{2\pi \times \sqrt{(L_{equ} \times C_t)}} = \frac{1}{2\pi \times \sqrt{L_s \times C_s}} = \frac{f_{osc}}{64} \text{ with} \quad (2)$$

$$C_t = \frac{C_{t1} \times C_{t2}}{C_{t1} + C_{t2}} \text{ and } \frac{1}{5} = \frac{C_{t1}}{C_{t1} + C_{t2}} \text{ and } L_{equ} = 200 \mu H$$

For the serial LC filter, at standard frequency (132.5 kHz),  $L_s = 3.3 \mu H$  and  $C_s = 470 \text{ nF}$  is a good compromise.  $C_{t1}$  and  $C_{t2}$  calculation for a carrier frequency of  $f_c$  can be done with the simple formula given in [Equation 3](#):

$$C_t = \frac{1}{4 \times \pi^2 \times f_c^2 \times 200 \times 10^{-6}} \quad (3)$$

$$C_{t1} = 1.25 \times C_t$$

$$C_{t2} = 5 \times C_t$$

where  $f_c$  is in Hertz;  $C_t$ ,  $C_{t1}$ ,  $C_{t2}$  in Farad.

### 3.3.2 Design example

Designer choices:

- Frequency band: no protocol used, so the 95 kHz to 125 kHz band is chosen.
- Carrier frequency: within this frequency range, a standard quartz crystal of 7.3728 MHz gives a carrier of 115.2 kHz.
- The components should be:
  - LC filter:  $L_s = 3.3 \mu H \pm 10 \%$  with  $R_s < 1 \Omega$ ,  $C_s = 630 \text{ nF} \pm 10 \%$  25 V
  - $C_c$ : coupling capacitor type X2 (230 V (RMS)), 470 nF
  - $C_t = 9.5 \text{ nF}$  (see [Equation 3](#) with  $f_c = 115 \text{ kHz}$ )  $\rightarrow C_{t1} = 12 \text{ nF} \pm 10 \%$ , 25 V;  
 $C_{t2} = 47 \text{ nF} \pm 10 \%$ , 25 V

With these components, one can simulate the transfer characteristic in transmission, reception and the input impedance.

This simulation does not take into account the effect of the transformer's core material and the parasitic capacitance of the windings. In fact, these simulation results have been compared with real measurements, and the behavior was very close to the computer analysis in a frequency range from 10 kHz to 10 MHz.

The last check of the transformer coupling is also a spectrum measurement on a CISPR16 load; a diagram is shown at the end of the chapter.

3.3.2.1 Reception mode — transfer characteristic of the coupling network

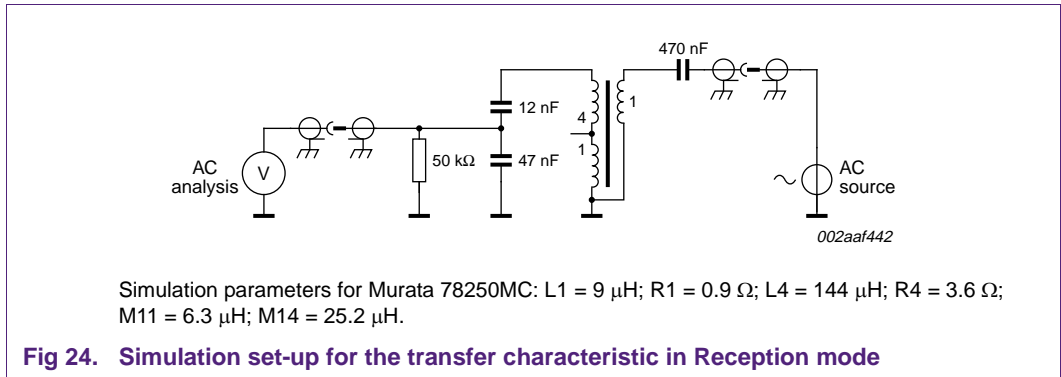


Fig 24. Simulation set-up for the transfer characteristic in Reception mode

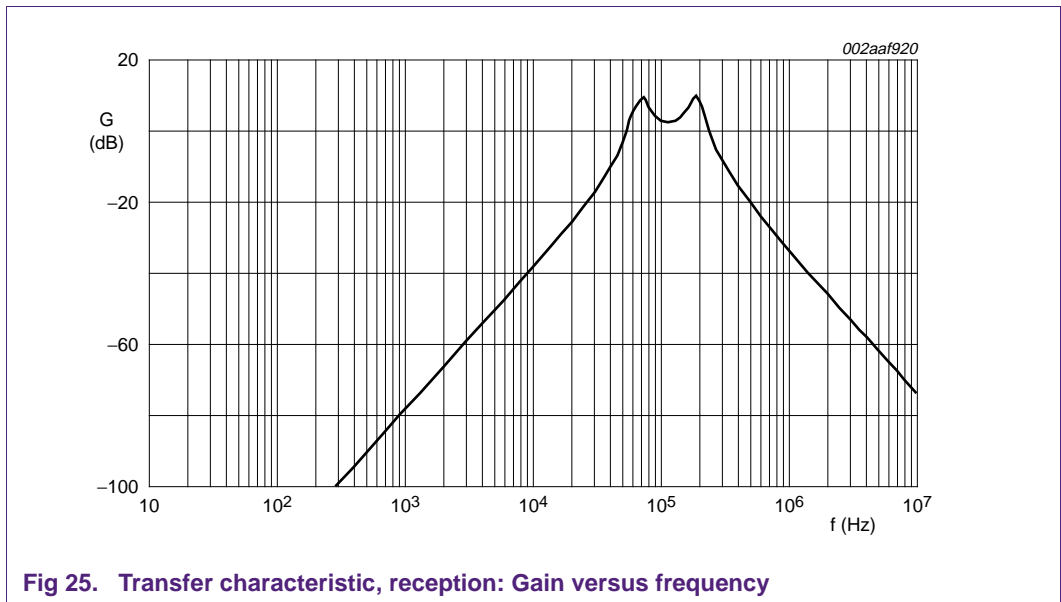
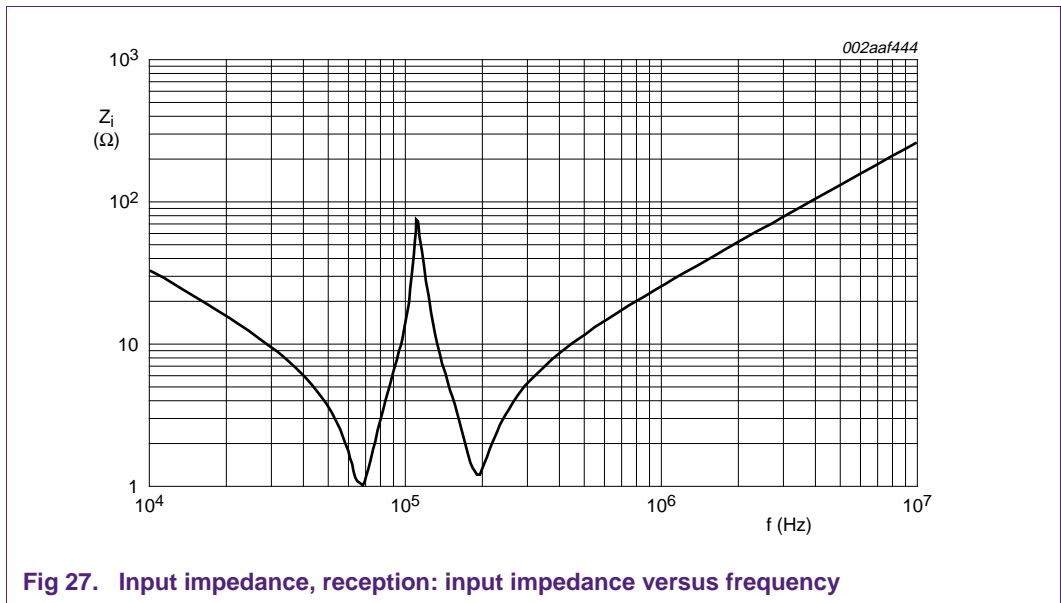
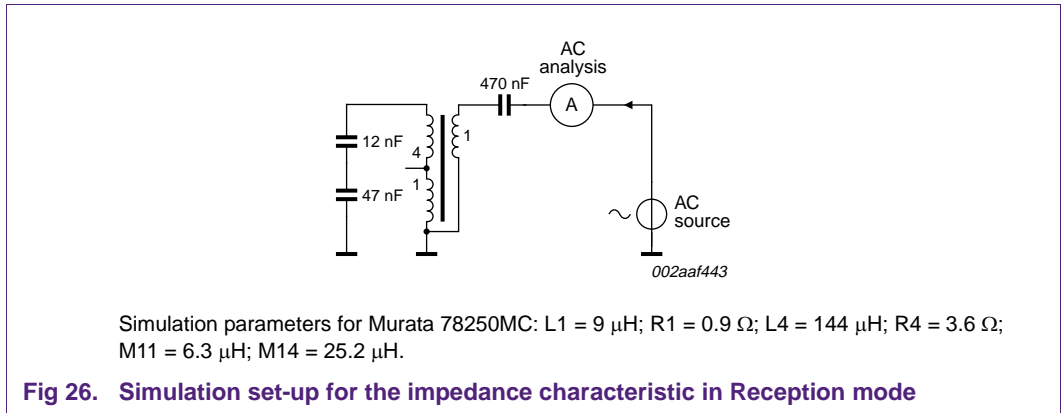


Fig 25. Transfer characteristic, reception: Gain versus frequency

3.3.2.2 Reception mode — impedance characteristic of the coupling network



The problem for this coupling network is the impedance limitation in reception, around the center frequency. One can see in [Figure 27](#) that the impedance is very low for two different frequencies, 70 kHz and 200 kHz. However, the input impedance is higher than 5  $\Omega$  within the 95 kHz to 148.5 kHz frequency range.

3.3.2.3 Transmission mode — transfer characteristic of the coupling network

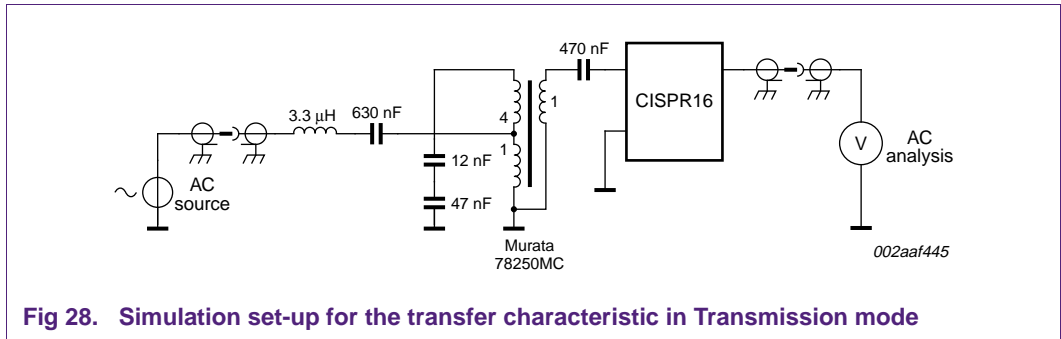


Fig 28. Simulation set-up for the transfer characteristic in Transmission mode

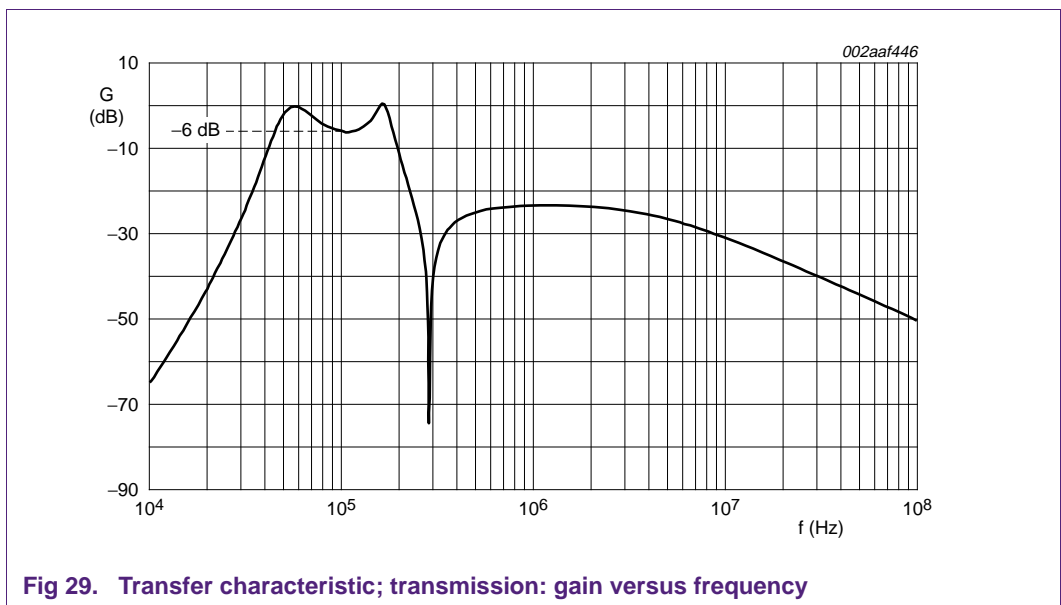
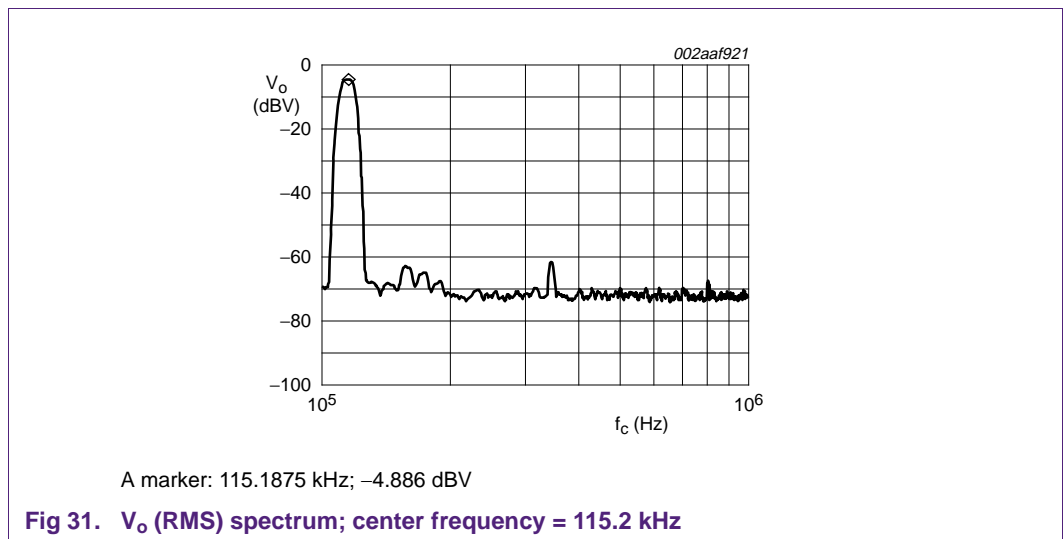
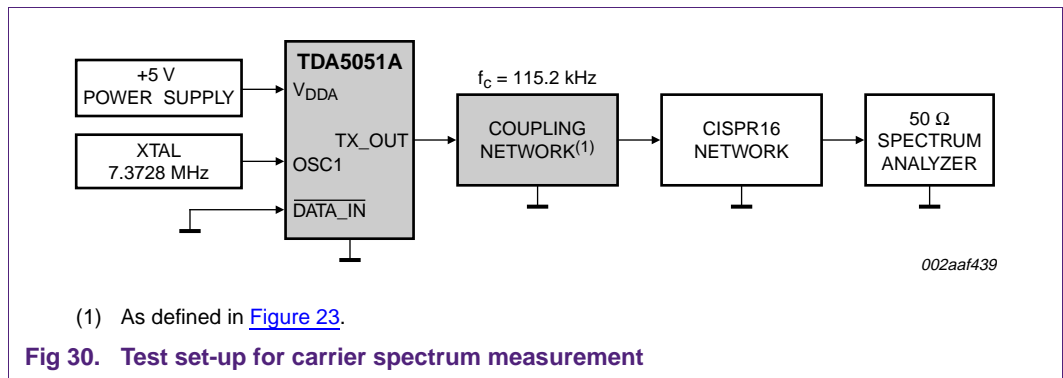


Fig 29. Transfer characteristic; transmission: gain versus frequency



3.3.2.4 Transmission mode — spectrum of the carrier signal with transformer coupling network



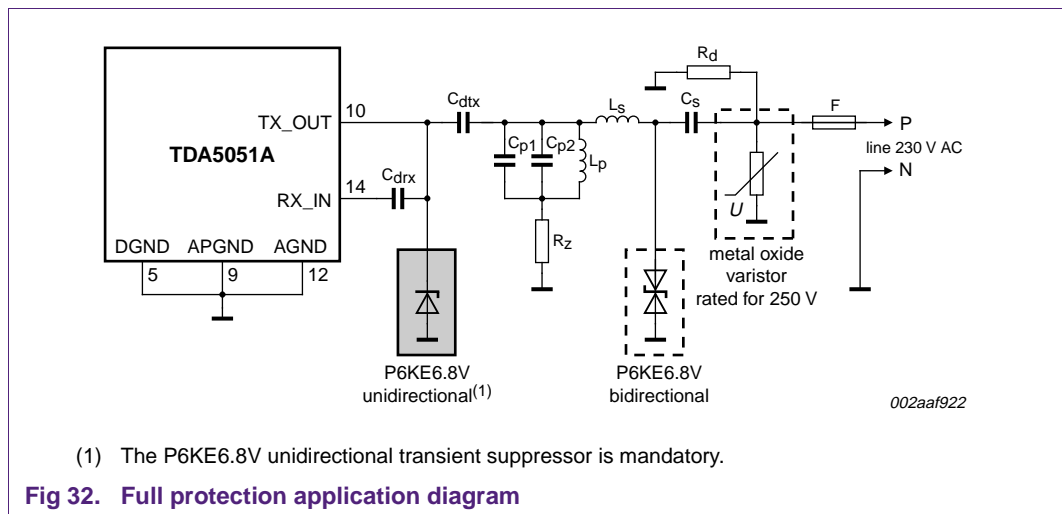
### 3.4 Transient and overvoltage protections - electrical hazard

#### 3.4.1 Introduction

- More than any other electronic equipment, a power line modem has to be protected against many risks of damage, mainly due to the direct connection to the mains. The TDA5051A is internally protected against electrostatic discharges, but **does not have a dedicated protection** for severe external stresses.
  - **Transient overstress during power-up:** The coupling network, LC filter or HF transformer, is basically a passive network having inductors and capacitors that are discharged before power-up. That means a particular behavior during power-up which may cause the modem **irreversible damage**.
  - **Overvoltage on the power line:** The power line of the modem is shared with other equipment, which may cause severe disturbances and overvoltage during operation or on/off switching. The power line itself may carry transient overvoltage due to indirect effects of lightning (protecting domestic electronic equipment from direct effects of lightning is not realistic and goes beyond the purpose of this note).
- The other protection aspect depends on the application and concerns the electrical hazards for people when using the power line equipment.
  - **Insulation with the mains:** If the application requires an insulation with the power line, the coupling network with HF transformer must be used. For software development, it is also recommended to use a transformer coupling, or to work on a dedicated power line, insulated from the mains with a 1 : 1 power transformer.
  - **Discharge of high voltage capacitors:** In some cases, the modem can be disconnected from the power line by the user of the system. If the coupling network is not loaded, the high voltage capacitors remain charged, and a shock hazard may exist.

#### 3.4.2 Coupling with LC filter

Figure 32 shows one of the best solutions for a complete protection of the modem. Obviously, it is not the cheapest, but it provides a high safety level.



The primary protection (optional) is possible with a Metal-Oxide Varistor (MOV), rated at 230 V power line operation. It will be able to limit overvoltage spikes which could damage the  $C_s$  (X2 type) capacitor. A problem may occur if a long or severe overvoltage is applied to the MOV: in this case the extra-fast fuse 'F' **must** be destroyed **before** the MOV itself!

Refer to the supplier's data sheet to verify that the set MOV-FUSE has an adequate overvoltage specification.

The second protection device (optional) is a bidirectional Transil, type P6KE6.8V, which limits the voltage applied to the  $C_{p1}$  and  $C_{p2}$  capacitors and the peak current into  $L_s$  and  $L_p$  inductors. If the designer decides to avoid the use of this protection, he has to measure the transient voltage applied on  $C_{p1}$  and  $C_{p2}$  and the peak current into the inductors  $L_s$  and  $L_p$ . Then, he must decide of voltage and current ratings for these components.

The last protection device is the unidirectional transient suppressor P6KE6.8V (or equivalent) which is **mandatory** in this application diagram. This device protects both TX\_OUT and RX\_IN pins from overvoltage. It protects also TX\_OUT from **negative transient voltage** which may **destroy the circuit's output amplifier**. This Transil must be connected directly to the TX\_OUT pin, as close as possible, with a strong short strip on the printed-circuit board.

The DC output voltage (2.5 V) of the TX\_OUT pin is used to bias the Transil in Transmission mode, in order to avoid carrier signal clipping and distortion.

It could be useful to keep in mind that a Transil has an equivalent capacitance of up to 4 nF for a unidirectional type (depending of the bias voltage) and half for a bidirectional one. That could explain some tuning variation when it is used with a narrow LC filter.

Then, a high value resistor  $R_d$  can be used to discharge  $C_s$  if the system is removed from the mains. The value could be chosen between 100 k $\Omega$  (1 W) and 1 M $\Omega$  ( $\frac{1}{4}$  W) depending of the requested time to discharge  $C_s$ .

### 3.4.3 Coupling with HF transformer

Figure 33 shows the complete coupling network with the protection components.

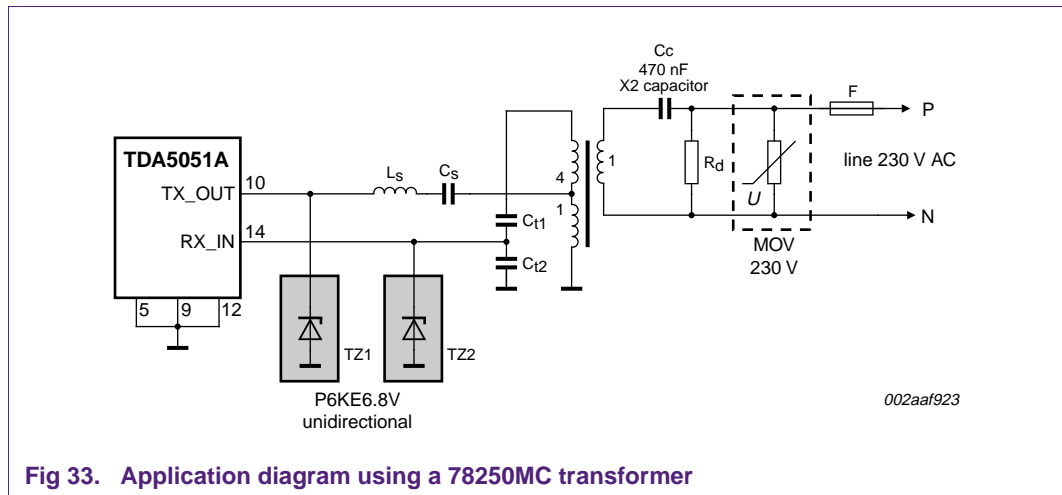


Fig 33. Application diagram using a 78250MC transformer

In this configuration, it is not so easy to protect both TX\_OUT and RX\_IN pins with only one Transil as shown in [Figure 32](#), because of the different connections with the transformer.

The two unidirectional Transils are now **mandatory** to clamp the transformer's surge voltage of the secondary windings and avoid any stress and reverse voltage at the TX\_OUT pin.

It may be possible to replace the unidirectional Transil TZ1 with a fast recovery diode, only used to clamp the negative transient voltage. In this configuration, the designer will have to check the maximum voltage applied at the TX\_OUT pin, for different overvoltage and stress on the line input; this voltage must be always lower than 7 V.

The MOV device is not mandatory, but recommended only if an appropriate fast fuse is used.

The  $R_d$  resistor may be omitted if the system is never disconnected from the mains, or if another load is always connected to the same power wires (for example, the primary winding of a power supply transformer).

In some cases, to improve the insulation with the mains and to guarantee the decoupling, it could be useful to add an extra  $C_c$  capacitor on the other power line wire of the system, as shown in [Figure 34](#). In this case, the value of these two X2 capacitors must be 1  $\mu\text{F}$ .

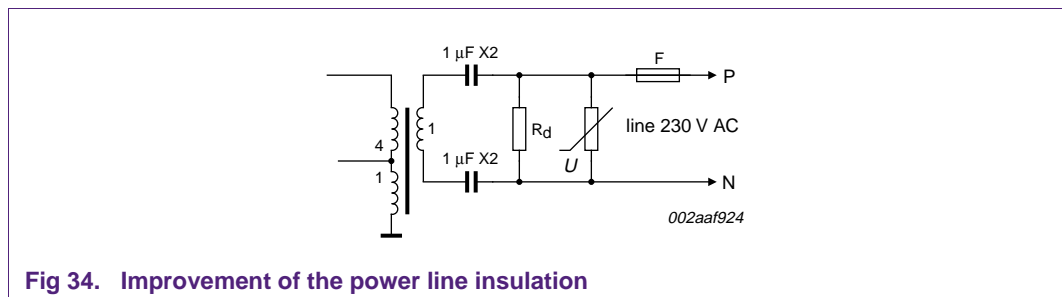


Fig 34. Improvement of the power line insulation

## 4. Connection with the controller

### 4.1 Clock configurations

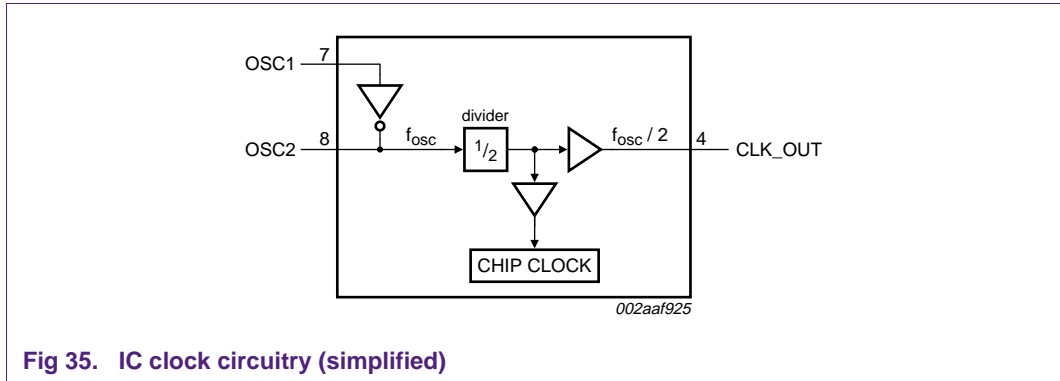


Fig 35. IC clock circuitry (simplified)

The TDA5051A can be used with two different clock configurations: external clock and on-chip clock.

#### 4.1.1 External clock

A clock signal, TTL/CMOS compatible, is applied to the OSC1 pin of the circuit and sets the operation frequency called  $f_{osc}$ . Then, the carrier and detection frequency is  $f_{osc} / 64$ .

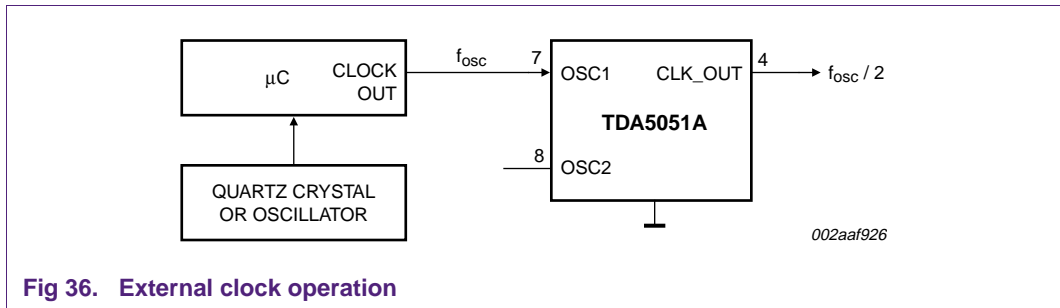


Fig 36. External clock operation

Table 11. External clock settings

| TDA5051A                        | External clock                         |
|---------------------------------|--|
| OSC1, pin 7                     | input; signal frequency $f_{osc}$      |
| OSC2, pin 8                     | <b>must be left open</b>               |
| CLK_OUT, pin 4                  | output; signal frequency $f_{osc} / 2$ |
| carrier and detection frequency | $f_{osc} / 64$                         |

#### 4.1.2 On-chip clock

An external quartz crystal is connected to the circuit and sets the operation frequency  $f_{osc}$ . In this configuration, the CLK\_OUT pin of the TDA5051A is a clock output, which is able to supply a TTL/CMOS compatible clock signal to an external controller, at an  $f_{osc} / 2$  frequency. The carrier and detection frequency is also  $f_{osc} / 64$ .

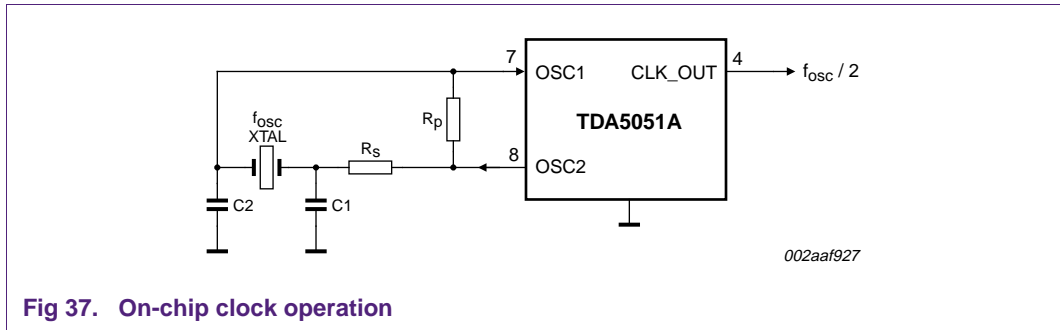


Table 12. On-chip clock settings

| TDA5051A                        | External clock                            |
|---------------------------------|---|
| OSC1, pin 7                     | external quartz crystal (XTAL) connection |
| OSC2, pin 8                     | external quartz crystal (XTAL) connection |
| CLK_OUT, pin 4                  | output; signal frequency $f_{osc} / 2$    |
| carrier and detection frequency | $f_{osc} / 64$                            |

The on-chip clock circuit is basically a Pierce oscillator, which uses an inverter implemented on the silicon and other external components. The  $R_p$  resistor is used to bias the inverter in the linear region and the  $R_s$  resistor limits the dissipation and the peak current in the crystal. The  $R_s$  resistor is not mandatory and could be avoided to reduce the number of external components.

This oscillator can operate within a very large frequency range, but for the recommended values of carrier frequency, defined in the EN50065-1 standard, the XTAL must be chosen between 6.2 MHz and 9.3 MHz. For these values, the external components must be chosen as shown in [Table 13](#).

Table 13. External component selection

| Component | Recommended values                               |
|-----------|--|
| C1 and C2 | 22 pF to 47 pF ceramic capacitors                |
| $R_p$     | 1 M $\Omega$ to 10 M $\Omega$                    |
| $R_s$     | 0 $\Omega$ to 3.9 k $\Omega$                     |
| XTAL      | HC49 standard quartz crystal; 6.2 MHz to 9.3 MHz |

For this oscillator, the requirements for a good start-up are:

- A loop gain larger than 5: that means an amplifier gain 5 times larger than the attenuation of the passive part.
- A loop phase of 360°: the inverter has a phase shift of 180° and the passive part must have the same.

With  $R_p = 2.2 \text{ M}\Omega$ ,  $R_s = 0 \text{ }\Omega$  and  $C1 = C2 = 27 \text{ pF}$ , a large set of crystals have been successfully checked for start-up and continuous operation, over the IC specified temperature range. However, the designer will have to check carefully the oscillator in the complete application.

## 4.2 Data signals — control signals

### 4.2.1 Connection to a microcontroller

The TDA5051A can be connected to any controller having a TTL/CMOS compatible I/O port, as shown in [Figure 38](#).

The PD connection is not mandatory and may be omitted if the PD mode is not used. Then, this pin could be tied to GND or could be left opened (the IC has an internal pull-down resistor).

The pins TEST1 and SCANTEST are only used for production tests. They have internal pull-up and pull-down resistors, but it is also possible to tie them to the correct level.

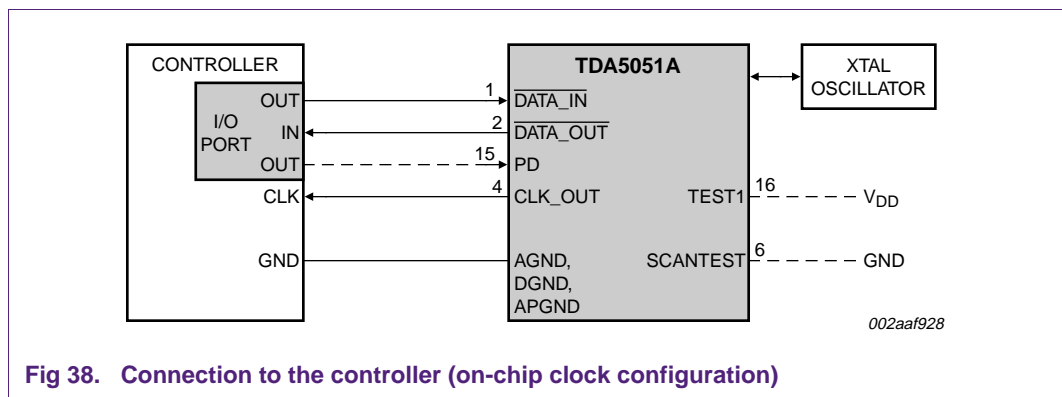


Fig 38. Connection to the controller (on-chip clock configuration)

$\overline{\text{DATA\_IN}}$  and  $\overline{\text{DATA\_OUT}}$  signals are active LOW, and special care must be taken with  $\overline{\text{DATA\_IN}}$ . As explained in the data sheet, after power-up, **this signal must be HIGH before starting any transmission**. If after power-up,  $\overline{\text{DATA\_IN}}$  remains LOW or undefined, the circuit may **stay in a dummy state**.

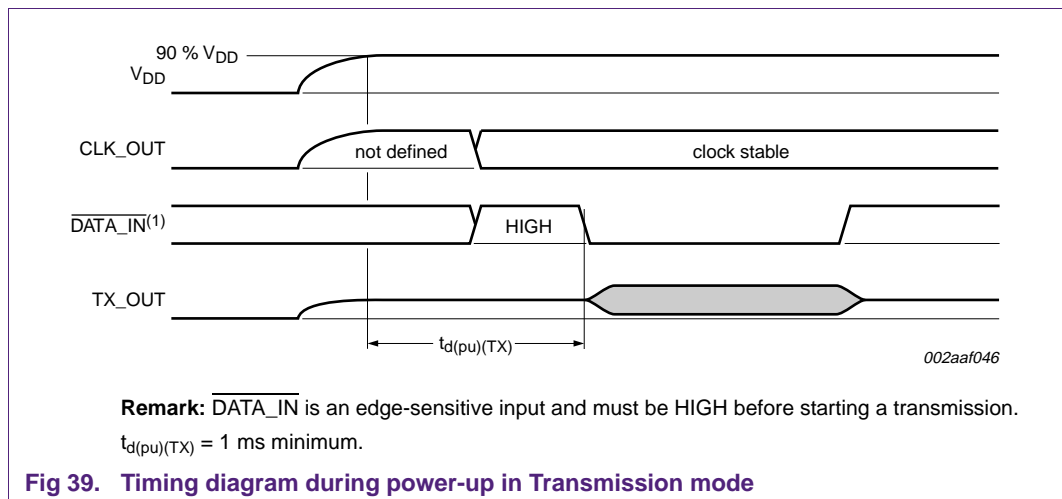


Fig 39. Timing diagram during power-up in Transmission mode

4.2.2 Connection to the controller for evaluation or software development

To prevent from electrical hazards or risks of damage to the equipment, it is important to choose the best development setup, which depends on the coupling configuration of the modem.

4.2.2.1 Modem coupled to the mains with HF transformer

This is probably the safest approach for the equipment and the designer! The power line has no common wire with the application and/or the equipment.

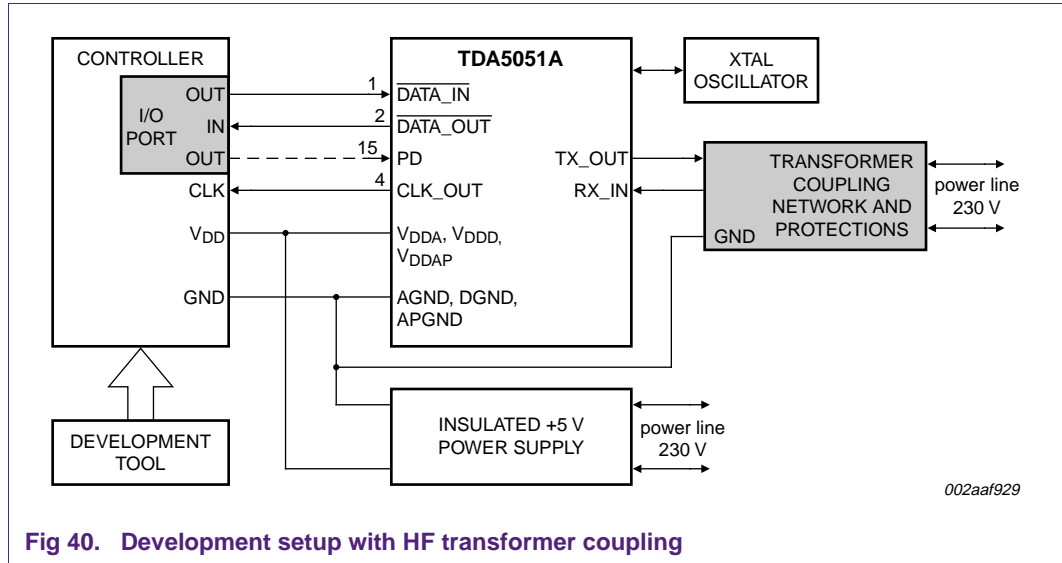


Fig 40. Development setup with HF transformer coupling

4.2.2.2 Modem coupled to the mains with LC filter

In this case, it is **mandatory** to use a 1 : 1 line insulation transformer, in order to create an artificial power line, used to connect together several modem applications. Then the GND wire of the application will be directly tied to one of the artificial power line.

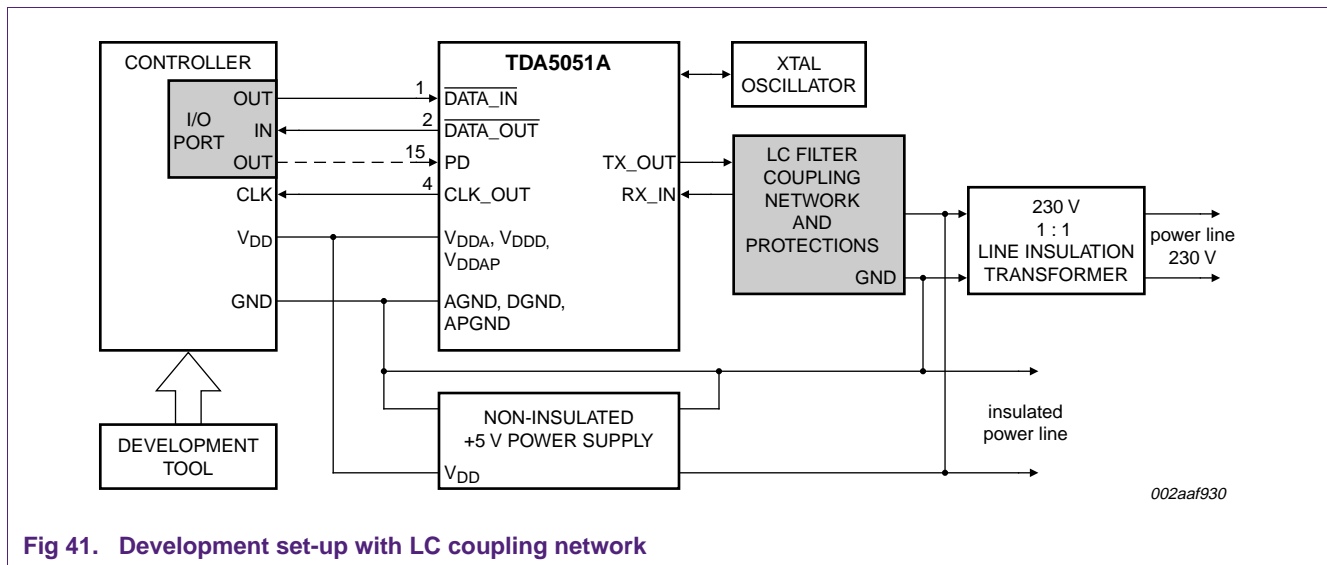


Fig 41. Development set-up with LC coupling network



4.2.2.3 Modem coupled to the mains with LC filter — Example of signals' insulation

It is possible to avoid the use of an artificial power line (as shown in Figure 42), even with a LC coupling network, by using electrical insulation of the TDA5051A data signals. That provides more realistic coupling conditions, because of the direct connection of the modem to the mains.

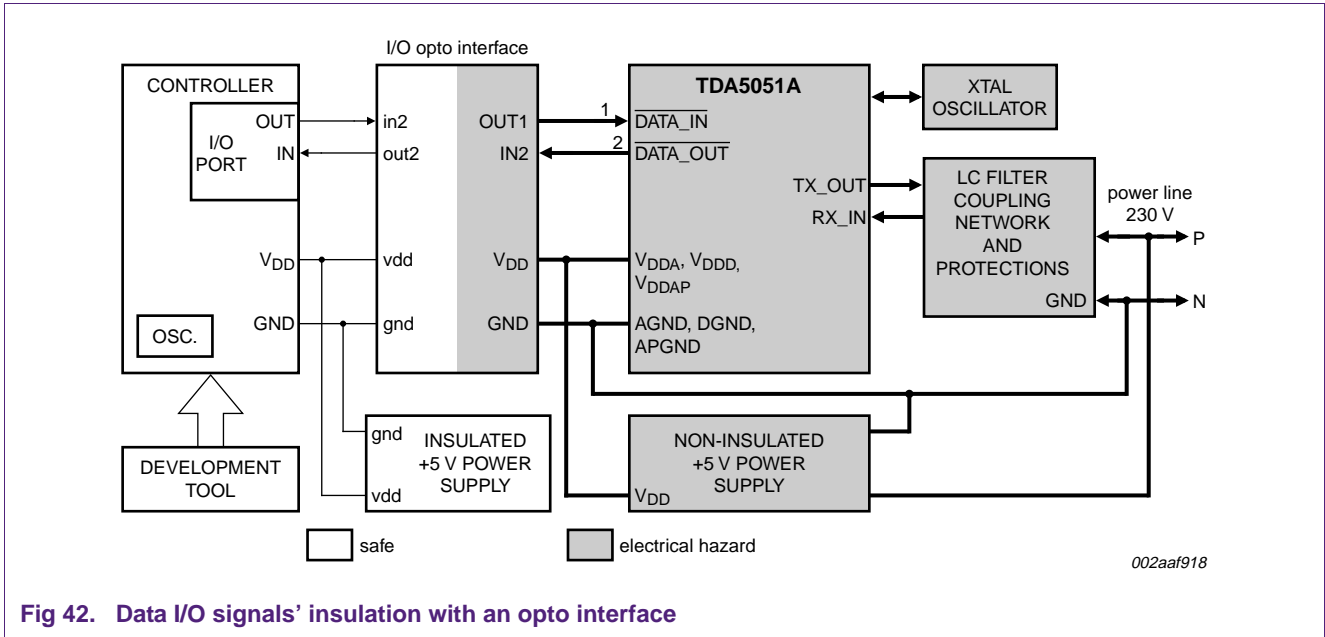


Fig 42. Data I/O signals' insulation with an opto interface

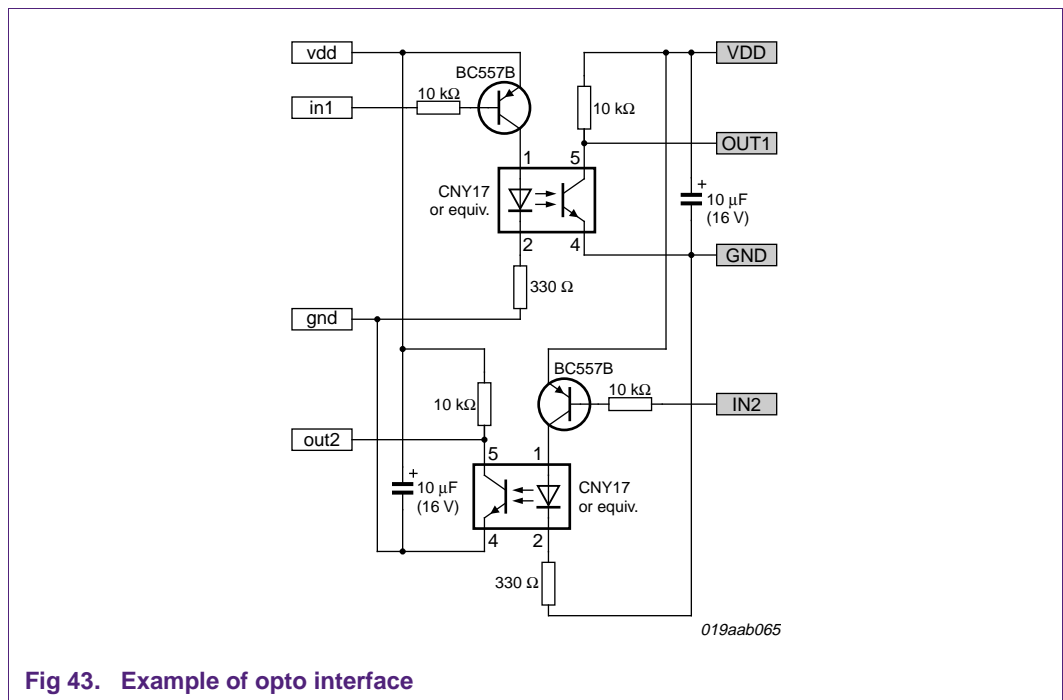


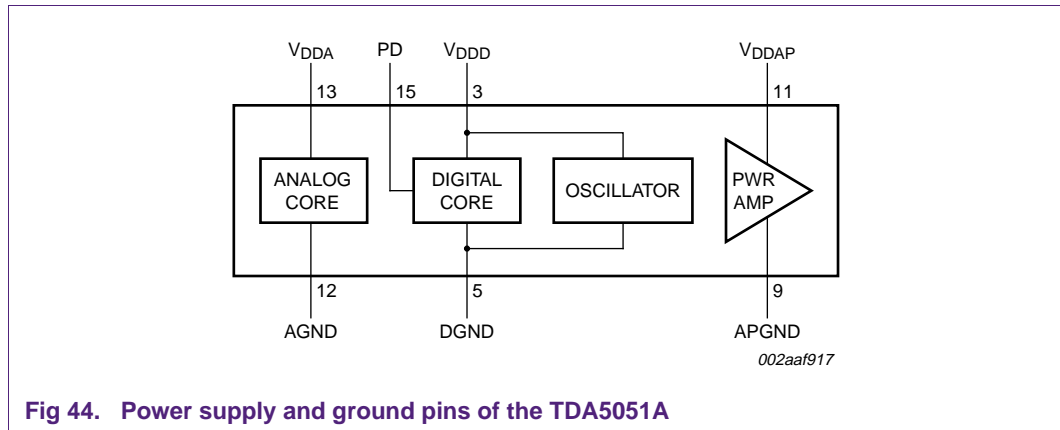
Fig 43. Example of opto interface

## 5. Power supply design

### 5.1 Power consumption

The TDA5051A has 6 pins dedicated to the power supply, corresponding to 3 groups of power supply / ground, as shown in [Figure 44](#).

In the application, the  $V_{DDA}$ - $V_{DDD}$ - $V_{DDAP}$  pins have to be connected together to the +5 V power supply. It is the same for the AGND-DGND-APGND pins, which must be connected to the ground.



**Fig 44. Power supply and ground pins of the TDA5051A**

As mentioned in the data sheet, the Power-Down (PD) pin only changes the behavior of the digital part of the modem and its consumption; the oscillator remains active and the CLK\_OUT signal continues to be generated to the controller.

The consumption of the modem depends on many parameters, like oscillator frequency and operation mode. However, the maximum ‘possible’ power consumption is the power amplifier, and depends on the power line impedance. [Table 14](#) shows different power consumption levels in different conditions, for a typical circuit.

**Table 14. Power consumption levels<sup>[1]</sup>**

| Conditions   | $I_{DDA}$ | $I_{DDD}$ | $I_{DDAP}$ | $I_{DD}$ total |
|--|-----------|-----------|------------|----------------|
| Standby mode <sup>[2]</sup> at 8.48 MHz                          | 12 mA     | 12 mA     | 0.05 mA    | 24 mA          |
| Reception mode <sup>[3]</sup> at 8.48 MHz                        | 12 mA     | 16 mA     | 0.05 mA    | 28 mA          |
| Power-down mode <sup>[4]</sup> at 8.48 MHz                       | 12 mA     | 2.5 mA    | 0.05 mA    | 14.5 mA        |
| Transmission mode <sup>[5]</sup> at 8.48 MHz; load = 30 $\Omega$ | 12 mA     | 16 mA     | 19 mA      | 47 mA          |
| Transmission mode <sup>[5]</sup> at 8.48 MHz; load = 10 $\Omega$ | 12 mA     | 16 mA     | 47 mA      | 75 mA          |
| Transmission mode <sup>[5]</sup> at 8.48 MHz; load = 1 $\Omega$  | 12 mA     | 16 mA     | 70 mA      | 98 mA          |

[1] Oscillator: external quartz crystal with  $R_s = 0 \Omega$ ,  $R_p = 2.2 M\Omega$ ,  $C1 = C2 = 27 pF$ , XTAL at 8.48 MHz;  $V_{DDA} = V_{DDD} = V_{DDAP} = +5 V$ ;  $T_{amb} = 25 \text{ }^\circ\text{C}$ .

[2] Standby mode: no signal applied at RX\_IN pin; no signal applied at  $\overline{\text{DATA\_IN}}$  pin.

[3] Reception mode: signal (at the carrier frequency) applied at RX\_IN with a 10 nF capacitor, 120 dB $\mu$ V amplitude.

[4] Power-down mode: PD pin is HIGH.

[5] Transmission mode:  $\overline{\text{DATA\_IN}} = 0$ , resistive load with a 10  $\mu$ F capacitor on the TX\_OUT pin.

It is important to notice that a **high peak current may be required** during low-impedance operation on heavily loaded power line, for example.

In order to prevent extra distortion of the output signal, and a good decoupling of the power supply, it is mandatory to connect, as close as possible, two capacitors: e.g., a high value electrolytic capacitor of 100  $\mu\text{F}$  to 200  $\mu\text{F}$  / 10 V and a 47 nF to 100 nF ceramic capacitor.

The ground strip on the printed-circuit board should be as large as possible (ground plane under the IC, if possible), and the connection between the IC and these capacitors should be very short.

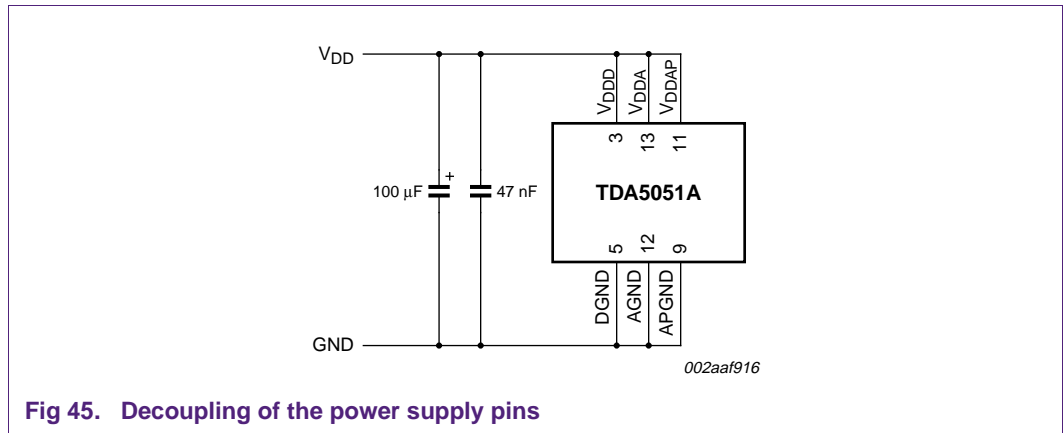


Fig 45. Decoupling of the power supply pins

### 5.2 Example of an R-C power supply

It is one of the most popular types of non-insulated power supply, which uses the 50 Hz impedance of a capacitor ( $C_s$ ) to supply a rectifier and a DC capacitor, followed by a linear +5 V regulator.

An example is shown in [Figure 46](#).

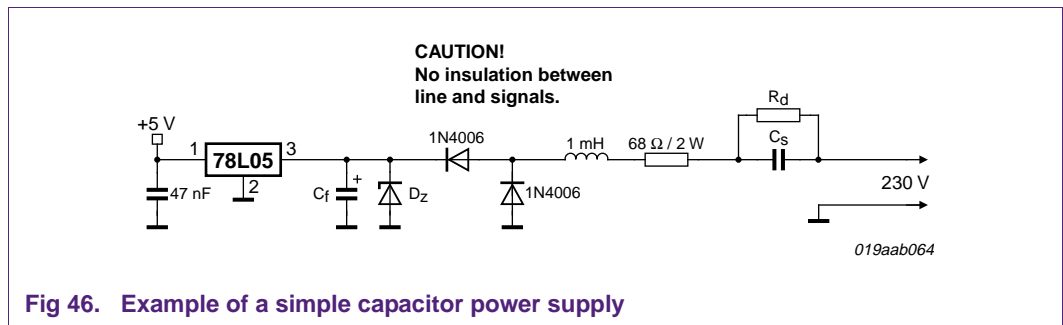


Fig 46. Example of a simple capacitor power supply

In this configuration, the designer must take into account several parameters:

- The  $C_s$  capacitor must be an X2 type, rated for 230 V power line operation.
- The input impedance of the passive network must be high in the modem operation frequency range, and must comply with the standards. For these reasons, an inductor of 1 mH is used with an extra 68  $\Omega$  resistor.
- During power-up, the peak current must be limited. This is also why the inductor/resistor set is before the rectifier.

- $D_z$  and  $C_f$  must be chosen to provide the minimum voltage required by the 78L05.
- If another type of linear regulator is used, the quiescent current must be as low as possible.
- To reduce the commutation noise induced by the rectifiers, it may be useful to add small capacitors (1 nF, for example) in parallel with the 1N4006 diodes.
- To discharge the high voltage capacitor  $C_s$ , a high value resistor  $R_d$  is used ([100 k $\Omega$ , 1 W] to [1 M $\Omega$ , 1/2 W], depending on the requested discharge time).

Table 15 gives an example of component values and the maximum output current of the power supply.

Table 15. Component values and maximum output current of the power supply

| $C_s$       | $D_z$        | $C_f$             | $I_{O(max)}$ |
|-------------|--------------|-------------------|--------------|
| 1 $\mu$ F   | 8.2 V, 1.3 W | 470 $\mu$ F, 16 V | 25 mA        |
| 1.5 $\mu$ F | 8.2 V, 1.3 W | 470 $\mu$ F, 16 V | 35 mA        |
| 2.2 $\mu$ F | 8.2 V, 1.3 W | 470 $\mu$ F, 16 V | 50 mA        |

### 5.2.1 R-C power supply improvement

It is possible to improve the output current of the power supply without increasing the size of the  $C_s$  capacitor by using a full bridge rectifier instead of the two diodes 1N4006 in Figure 46.

The efficiency is twice as good for the same value of  $C_s$  capacitor, but it is not possible to couple the modem to the power line with an LC filter. The ground connection of the modem to the power line is lost, then it is **mandatory to use an HF coupling transformer**.

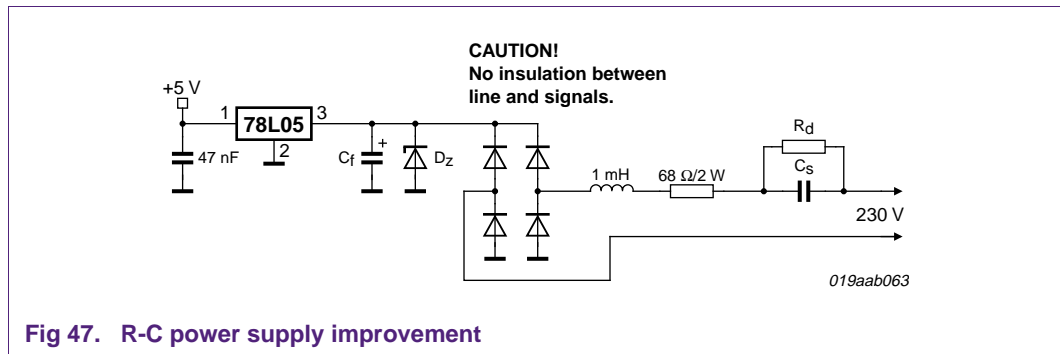


Fig 47. R-C power supply improvement

Table 16. Component values and maximum output current of the improved power supply

| $C_s$       | $D_z$        | $C_f$             | $I_{O(max)}$ |
|-------------|--------------|-------------------|--------------|
| 1 $\mu$ F   | 8.2 V, 1.3 W | 470 $\mu$ F, 16 V | 50 mA        |
| 1.5 $\mu$ F | 8.2 V, 1.3 W | 470 $\mu$ F, 16 V | 70 mA        |
| 2.2 $\mu$ F | 8.2 V, 1.3 W | 470 $\mu$ F, 16 V | 100 mA       |

### 5.3 Example of switching mode power supply

In order to reduce the size of the components, a solution could be to use an R-C power supply in association with a switch mode converter. The R-C supply is used to reduce the mains voltage from 230 V AC to 28 V DC, for example, and then the switch mode converter provides the +5 V regulated output.

The quiescent current of the switch mode regulator must be as low as possible, and the switching frequency (or its harmonics) must be chosen to avoid the modem band.

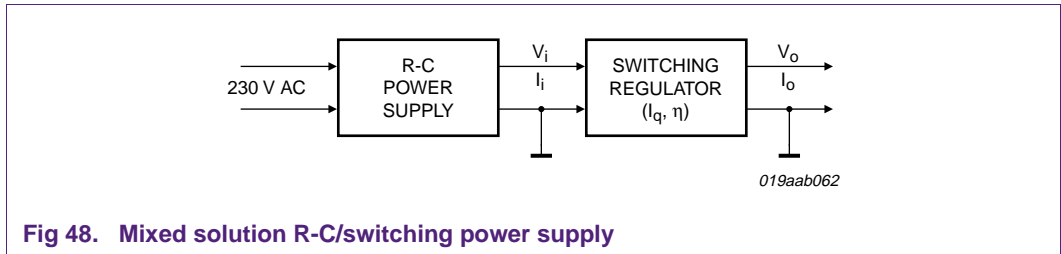


Fig 48. Mixed solution R-C/switching power supply

$$I_i = \frac{V_o \times I_o}{V_i \times \eta} + I_q \tag{4}$$

Where:

$V_i$  = input voltage of the regulator

$I_i$  = input current

$V_o$  = output voltage

$I_o$  = output current

$I_q$  = quiescent current

$\eta$  = efficiency of the switching converter

Figure 49 is an example of power supply using Linear Technology LT1372 500 kHz high efficiency switching regulator.

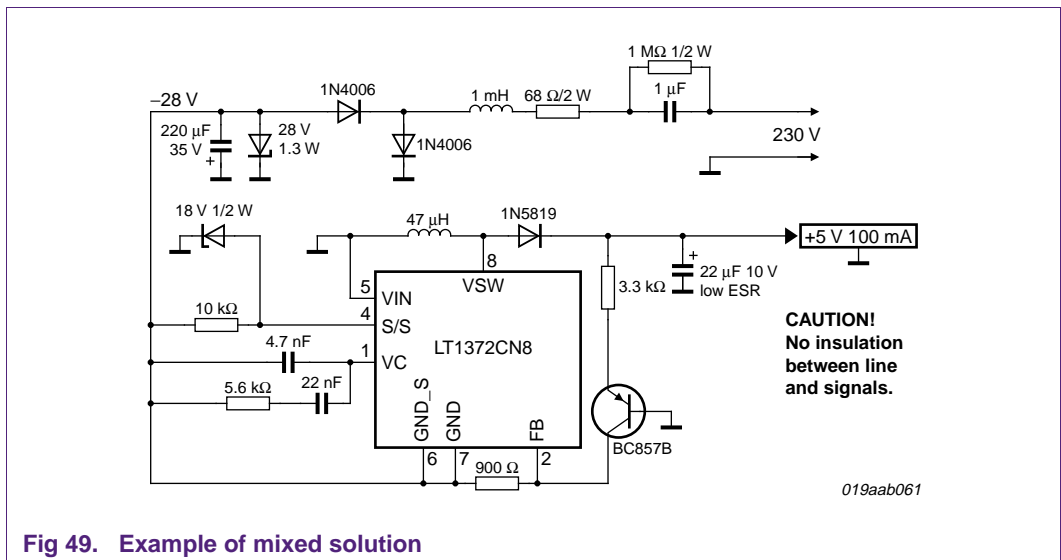


Fig 49. Example of mixed solution

6. TDA5051A power line modem demonstration board

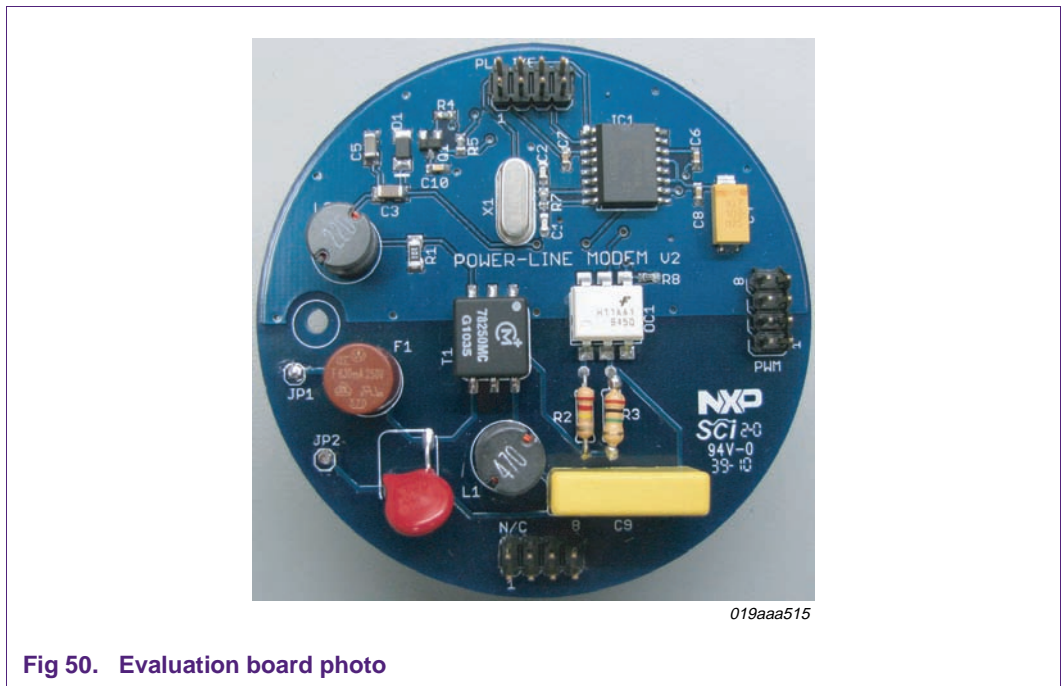


Fig 50. Evaluation board photo

**WARNING**

**Lethal voltage and fire ignition hazard**



The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel that is qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

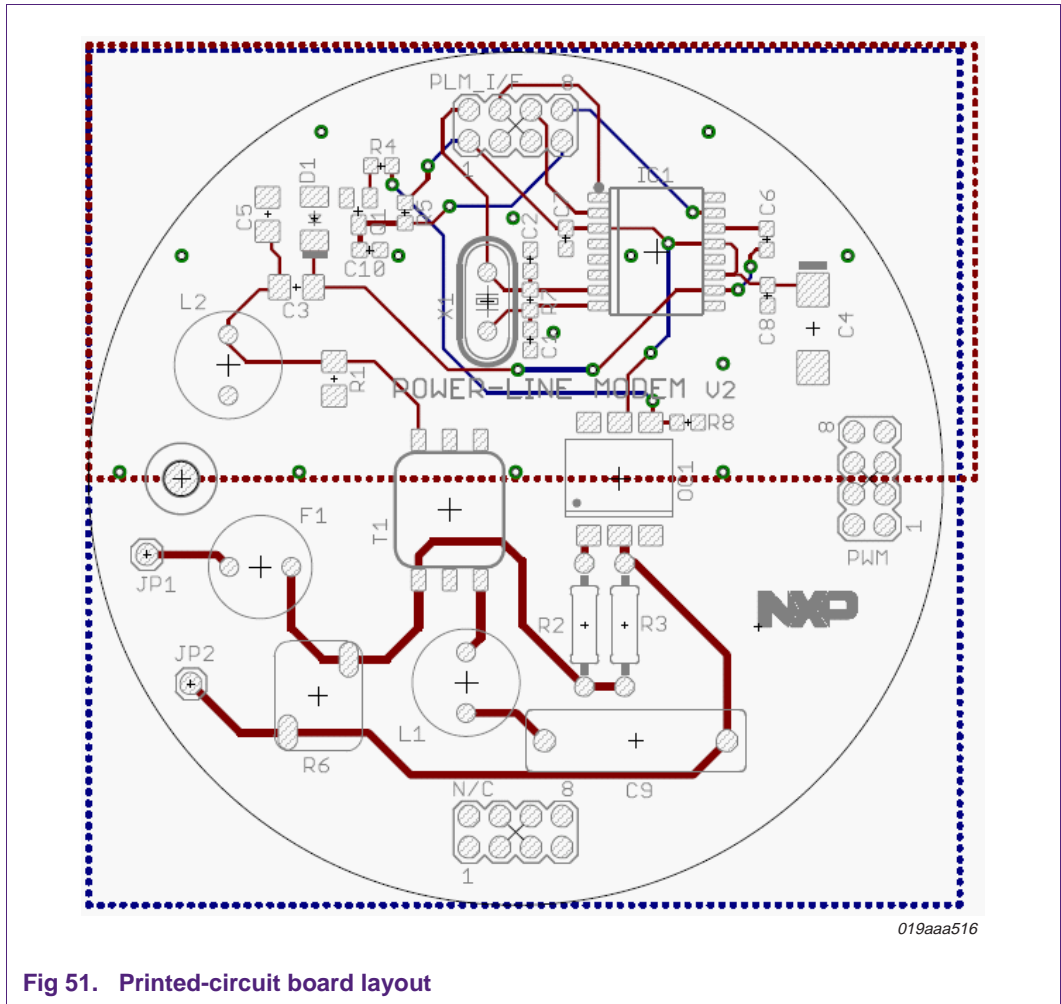


Fig 51. Printed-circuit board layout

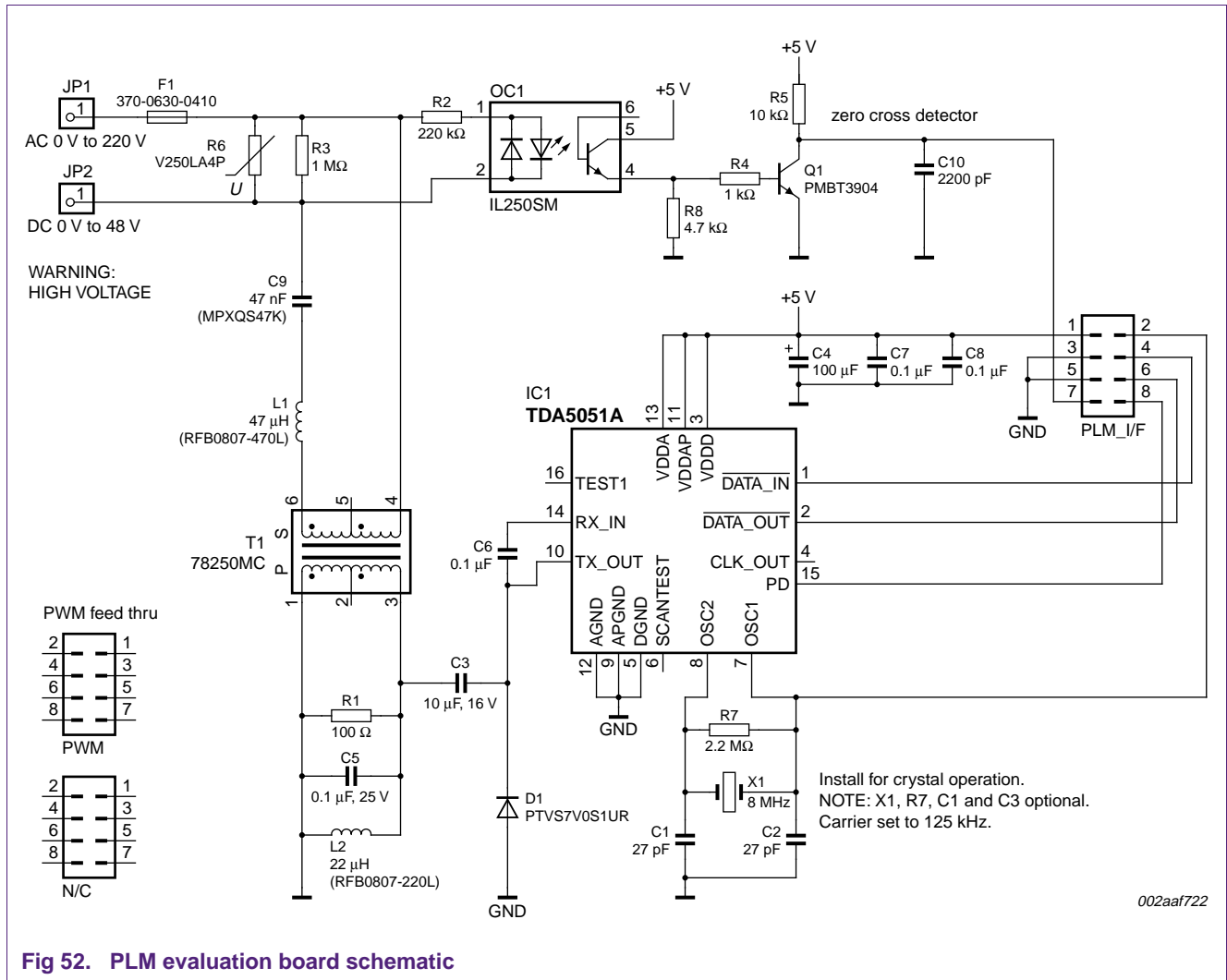


Fig 52. PLM evaluation board schematic



Table 17. Power line modem Bill Of Materials (BOM)

| Component         | Description             | Manufacturer | Package             | Type number    |
|-------------------|-------------------------|--------------|---------------------|----------------|
| C1 <sup>[1]</sup> | 27 pF                   |              | C0603               |                |
| C2 <sup>[1]</sup> | 27 pF                   |              | C0603               |                |
| C3                | 10 $\mu$ F, 16 V        |              | C1206               |                |
| C4                | 100 $\mu$ F             |              | CT7343              |                |
| C5                | 0.1 $\mu$ F at 25 V     |              | C1206               |                |
| C6                | 0.01 $\mu$ F            |              | C0603               |                |
| C7                | 0.1 $\mu$ F at 25 V     |              | C0603               |                |
| C8                | 0.1 $\mu$ F at 25 V     |              | C0603               |                |
| C9                | 47 nF (MPXQS47K)        |              |                     | C150-054X183   |
| C10               | 2200 pF                 |              | C0603               |                |
| D1                | PTVS7V0S1UR             | NXP          | SOD123,<br>Mini-SMA | CGRM4001-G     |
| F1                | FUSELITTLEFUSE_S370     | Little Fuse  | LITTLE_S370         | 370-0630-0410  |
| IC1               | Power Line Modem        | NXP          | SO16W               | TDA5051AT      |
| JP1               | header                  |              | 1X01                |                |
| JP2               | header                  |              | 1X01                |                |
| L1                | 47 $\mu$ H inductor     | Coilcraft    | RFB0807             | RFB0807-470L   |
| L2                | 22 $\mu$ H inductor     | Coilcraft    | RFB0807             | RFB0807-220L   |
| N/C               |                         |              | MA04-2              | MA04-2         |
| OC1               | IL250SM                 |              | IL250SM             | DIL6-SMD       |
| PLM_I/F           |                         |              | MA04-2              | MA04-2         |
| PWM               |                         |              | MA04-2              | MA04-2         |
| Q1                | transistor              | NXP          | SOT23               | PMBT3904       |
| R1                | 100 $\Omega$ resistor   |              | R1206               |                |
| R2                | 220 k $\Omega$ resistor |              | 0207/10             |                |
| R3                | 1 M $\Omega$ resistor   |              | 0207/10             |                |
| R4                | 1 k $\Omega$ resistor   |              | R0603               |                |
| R5                | 10 k $\Omega$ resistor  |              | R0603               |                |
| R6                | V250LA4P resistor       |              | V250LA4P            |                |
| R7 <sup>[1]</sup> | 2.2 M $\Omega$ resistor |              | R0603               |                |
| R8                | 4.7 k $\Omega$ resistor |              | R0603               |                |
| T1 <sup>[2]</sup> | transformer             | Murata       | 78250               | 78250MC        |
| X1                | 8.00 MHz crystal        |              | HC49U-V             | CRYSTALHC49U-V |

[1] Optional for XTAL.

[2] Specifications for component T1 signal transformer can be found at [www.nxp.com/redirect/murata-ps.com/data/magnetics](http://www.nxp.com/redirect/murata-ps.com/data/magnetics).

## 7. Abbreviations

**Table 18. Abbreviations**

| <b>Acronym</b> | <b>Description</b>                      |
|----------------|---|
| AGC            | Automatic Gain Control                  |
| ASK            | Amplitude Shift Keying                  |
| CMOS           | Complementary Metal-Oxide Semiconductor |
| DAC            | Digital-to-Analog Converter             |
| ESD            | ElectroStatic Discharge                 |
| HF             | High-Frequency                          |
| IC             | Integrated Circuit                      |
| LC             | inductor-capacitor filter               |
| MOV            | Metal-Oxide Varistor                    |
| NRZ            | Non-Return to Zero                      |
| PD             | Power-Down                              |
| PLM            | Power Line Modem                        |
| RMS            | Root Mean Squared                       |
| ROM            | Read-Only Memory                        |
| TTL            | Transistor-Transistor Logic             |

## 8. Legal information

### 8.1 Definitions

**Draft** — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

### 8.2 Disclaimers

**Limited warranty and liability** — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the *Terms and conditions of commercial sale* of NXP Semiconductors.

**Right to make changes** — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

**Suitability for use** — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or

malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors accepts no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

**Applications** — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

**Export control** — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from national authorities.

### 8.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

9. Contents

|          |  |           |            |  |           |
|----------|--|-----------|------------|--|-----------|
| <b>1</b> | <b>Introduction</b> . . . . .  | <b>3</b>  | <b>3.4</b> | Transient and overvoltage protections - electrical hazard. . . . .                   | 26        |
| 1.1      | TDA5051A ASK modem for power line data transmission . . . . .                                  | 3         | 3.4.1      | Introduction . . . . .   | 26        |
| 1.1.1    | Main features of the IC . . . . .  | 3         | 3.4.2      | Coupling with LC filter . . . . .  | 26        |
| 1.2      | Block diagram . . . . .  | 5         | 3.4.3      | Coupling with HF transformer . . . . .   | 27        |
| 1.3      | Pinning . . . . .  | 6         | <b>4</b>   | <b>Connection with the controller</b> . . . . .                                      | <b>29</b> |
| <b>2</b> | <b>Compliance with standards</b> . . . . .   | <b>7</b>  | 4.1        | Clock configurations. . . . .  | 29        |
| 2.1      | Compliance with EN50065-1 . . . . .  | 7         | 4.1.1      | External clock. . . . .  | 29        |
| 2.1.1    | Choice of the carrier frequency . . . . .  | 7         | 4.1.2      | On-chip clock . . . . .  | 29        |
| 2.1.2    | Modem output voltage . . . . .   | 8         | 4.2        | Data signals — control signals. . . . .  | 31        |
| 2.1.3    | Limiting conducted power line disturbances. . . . .  | 8         | 4.2.1      | Connection to a microcontroller . . . . .  | 31        |
| 2.2      | Compliance with EN50065-2 (project stage) . . . . .  | 9         | 4.2.2      | Connection to the controller for evaluation or software development . . . . .        | 32        |
| 2.2.1    | Immunity requirements: narrowband conducted interferences . . . . .                            | 9         | 4.2.2.1    | Modem coupled to the mains with HF transformer. . . . .                              | 32        |
| 2.2.2    | Immunity requirements: broadband noise interferences. . . . .                                  | 10        | 4.2.2.2    | Modem coupled to the mains with LC filter . . . . .                                  | 32        |
| 2.2.3    | Input impedance of the power line equipment . . . . .  | 10        | 4.2.2.3    | Modem coupled to the mains with LC filter — Example of signals' insulation . . . . . | 33        |
| <b>3</b> | <b>Coupling with the power line</b> . . . . .  | <b>11</b> | <b>5</b>   | <b>Power supply design</b> . . . . .   | <b>34</b> |
| 3.1      | Introduction. . . . .  | 11        | 5.1        | Power consumption . . . . .  | 34        |
| 3.1.1    | Decoupling TX_OUT and RX_IN pins . . . . .   | 11        | 5.2        | Example of an R-C power supply . . . . .   | 35        |
| 3.1.2    | Filter . . . . .   | 11        | 5.2.1      | R-C power supply improvement. . . . .  | 36        |
| 3.2      | Low cost coupling . . . . .  | 13        | 5.3        | Example of switching mode power supply. . . . .                                      | 37        |
| 3.2.1    | Introduction. . . . .  | 13        | <b>6</b>   | <b>TDA5051A power line modem demonstration board</b> . . . . .                       | <b>38</b> |
| 3.2.1.1  | DC decoupling of TX_OUT and RX_IN . . . . .  | 13        | <b>7</b>   | <b>Abbreviations</b> . . . . .   | <b>42</b> |
| 3.2.1.2  | Design of the LC filter . . . . .  | 13        | <b>8</b>   | <b>Legal information</b> . . . . .   | <b>43</b> |
| 3.2.2    | Design example of a typical coupling network . . . . .   | 14        | 8.1        | Definitions . . . . .  | 43        |
| 3.2.2.1  | Reception mode — transfer characteristic of the LC filter . . . . .                            | 15        | 8.2        | Disclaimers . . . . .  | 43        |
| 3.2.2.2  | Reception mode — input impedance of the LC filter . . . . .                                    | 16        | 8.3        | Trademarks . . . . .   | 43        |
| 3.2.2.3  | Transmission mode — transfer characteristic of the LC filter with a CISPR16 load. . . . .      | 17        | <b>9</b>   | <b>Contents.</b> . . . . .   | <b>44</b> |
| 3.2.2.4  | Transmission mode — efficiency of the LC filter . . . . .                                      | 18        |            |  |           |
| 3.2.2.5  | Transmission mode — spectrum of the carrier signal with low cost coupling network . . . . .    | 19        |            |  |           |
| 3.3      | Coupling with HF transformer. . . . .  | 20        |            |  |           |
| 3.3.1    | Introduction. . . . .  | 20        |            |  |           |
| 3.3.2    | Design example . . . . .   | 21        |            |  |           |
| 3.3.2.1  | Reception mode — transfer characteristic of the coupling network. . . . .                      | 22        |            |  |           |
| 3.3.2.2  | Reception mode — impedance characteristic of the coupling network. . . . .                     | 23        |            |  |           |
| 3.3.2.3  | Transmission mode — transfer characteristic of the coupling network. . . . .                   | 24        |            |  |           |
| 3.3.2.4  | Transmission mode — spectrum of the carrier signal with transformer coupling network . . . . . | 25        |            |  |           |

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.

© NXP B.V. 2010. All rights reserved.

For more information, please visit: <http://www.nxp.com>  
 For sales office addresses, please send an email to: [salesaddresses@nxp.com](mailto:salesaddresses@nxp.com)

Date of release: 17 December 2010

Document identifier: AN10903

## X-ON Electronics

Largest Supplier of Electrical and Electronic Components

*Click to view similar products for [nxp](#) manufacturer:*

Other Similar products are found below :

[MC13211R2](#) [PCA9518PW,112](#) [LFSTBEB865X](#) [MC33399PEFR2](#) [PCA9551PW,112](#) [MC34825EPR2](#) [CBTW28DD14AETJ](#) [PCF8583P](#)  
[MC68340AB16E](#) [MC8640DTVJ1250HE](#) [EVBCRTOUCH](#) [MC9S08PT16AVLC](#) [MC9S08PT8AVTG](#) [MC9S08SH32CTL](#) [MCF54415CMJ250](#)  
[MCIMX6Q-SDB](#) [MCIMX6SX-SDB](#) [74ALVC125BQ,115](#) [74HC4050N](#) [74HC4514N](#) [MK21FN1M0AVLQ12](#) [MKV30F128VFM10](#) [FRDM-K66F](#) [FRDM-KW40Z](#) [FRDM-MC-LVBLDC](#) [PESD18VF1BSFYL](#) [PMF63UNEX](#) [PSMN4R0-60YS,115](#) [HEF4028BPN](#) [RAPPID-567XFSW](#)  
[MPC565MVR56](#) [MPC574XG-176DS](#) [MPC860PCVR66D4](#) [BT137-600E](#) [BT139X-600.127](#) [BUK7628-100A118](#) [BUK765R0-100E.118](#)  
[BZT52H-B9V1.115](#) [BZV85-C3V9.113](#) [BZX79-C47.113](#) [P5020NSE7VNB](#) [S12ZVML12EVBLIN](#) [SCC2692AC1N40](#) [LPC1785FBD208K](#)  
[LPC2124FBD64/01](#) [LS1020ASN7KQB](#) [LS1020AXN7HNB](#) [LS1020AXN7KQB](#) [LS1043ASE7PQA](#) [T1023RDB-PC](#)