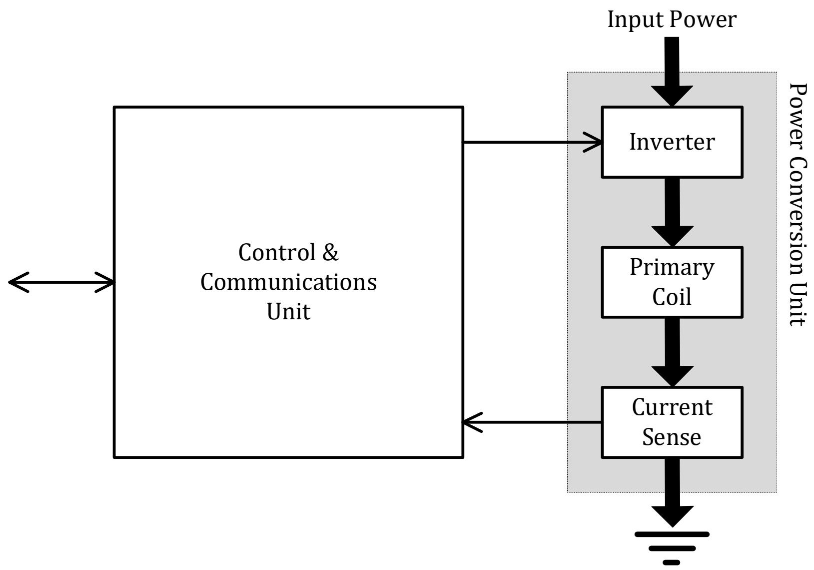
2.2.11.2 Power Transmitter design A11a

Power Transmitter design A11a enables Guided Positioning. Figure 35 illustrates the functional block diagram of this design, which consists of two major functional units, namely a Power Conversion Unit and a Communications and Control Unit.

Figure 35. Functional block diagram of Power Transmitter design A11a



The Power Conversion Unit on the right-hand side of Figure 35 comprises the analog parts of the design. The inverter converts the DC input to an AC waveform that drives a resonant circuit, which consists of the Primary Coil plus a series capacitor. Finally, the current sense monitors the Primary Coil current.

The Communications and Control Unit on the left-hand side of Figure 35 comprises the digital logic part of the design. This unit receives and decodes messages from the Power Receiver, executes the relevant power control algorithms and protocols, and drives the frequency of the AC waveform to control the power transfer. The Communications and Control Unit also interfaces with other subsystems of the Base Station, e.g. for user interface purposes.

2.2.11.2.1 Mechanical details

Power Transmitter design A11a includes a single Primary Coil as defined in Section 2.2.11.1.1.1, Shielding as defined in Section 2.2.11.1.1.2, an Interface Surface as defined in Section 2.2.11.1.1.3, and an alignment aid as defined in Section 2.2.11.1.1.4.

2.2.11.2.1.1 *Primary Coil*

The Primary Coil is of the wire-wound type, and consists of no. 17 AWG (1.15 mm diameter) type 2 litz wire having 105 strands of no. 40 AWG (0.08 mm diameter), or equivalent. As shown in Figure 36, the Primary Coil has a circular shape and consists of one or two layers. Table 25 lists the dimensions of the Primary Coil.

Figure 36. Primary Coil of Power Transmitter design A11a

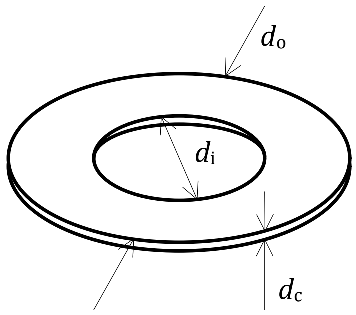


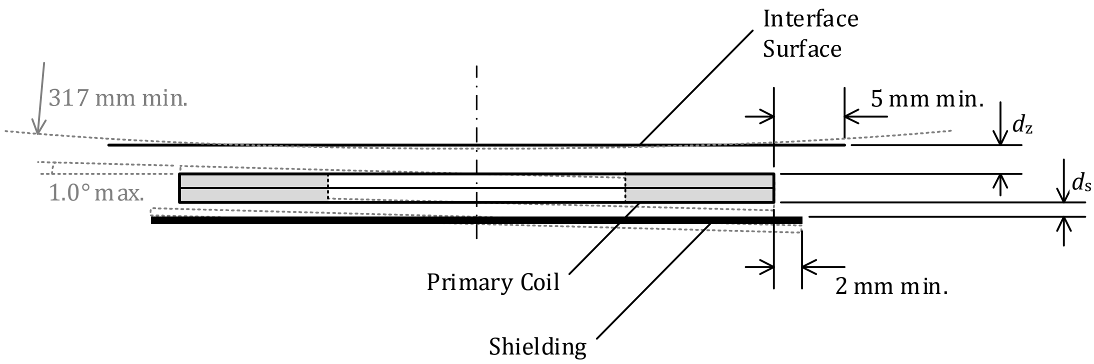
Table 25. Primary Coil parameters of Power Transmitter design A11a

Parameter	Symbol	Value
Outer diameter	d_o	$44^{\pm 1.5}$ mm
Inner diameter	d_i	$20.5^{\pm 0.5}$ mm
Thickness	d_c	$2.1^{+0.5}$ mm
Number of turns per layer	N	10 (5 bifilar turns)
Number of layers	–	1 or 2

2.2.11.2.1.2 *Shielding*

As shown in Figure 37, Shielding protects the Base Station from the magnetic field that is generated in the Primary Coil. The Shielding should be Ni-Zn or Mn-Zn ferrite and should be at least 0.5 mm thick. The Shielding extends to at least 2 mm beyond the outer diameter of the Primary Coil, and is placed below the Primary Coil at a distance of at most $d_s = 1.0$ mm.

Figure 37. Primary Coil assembly of Power Transmitter design A11a



2.2.11.2.1.3 Interface Surface

As shown in Figure 37, the distance from the Primary Coil to the Interface Surface of the Base Station is $d_z = 2^{+0.5}_{-0.25}$ mm, across the top face of the Primary Coil. In addition, the Interface Surface of the Base Station extends at least 5 mm beyond the outer diameter of the Primary Coil.

NOTE This Primary-Coil-to-Interface-Surface distance implies that the tilt angle between the Primary Coil and a flat Interface Surface is at most 1.0°. Alternatively, in case of a non-flat Interface Surface, this Primary-Coil-to-Interface-Surface distance implies a radius of curvature of the Interface Surface of at least 317 mm, centered on the Primary Coil. See Figure 37.

2.2.11.2.1.4 Alignment aid

The user manual of the Base Station containing a type A11a Power Transmitter shall have information about the location of its Active Area(s).

For the best user experience, it is recommended to employ at least one user feedback mechanism during Mobile Device positioning to help alignment.

NOTE Examples of Base Station alignment aids to assist the user positioning of the Mobile Device include:

- A marked Interface Surface to indicate the location of the Active Area(s)—e.g. by means of the logo or other visual marking, lighting, etc.
- A visual feedback display—e.g. by means of illuminating an LED to indicate proper alignment.
- An audible or haptic feedback mechanism.

2.2.11.2.1.5 Inter coil separation

If the Base Station contains multiple type A11a Power Transmitters, the Primary Coils of any pair of those Power Transmitters shall have a center-to-center distance of at least 50 mm.

2.2.11.2.2 Electrical details

As shown in Figure 38, Power Transmitter design A11a uses a full-bridge inverter to drive the Primary Coil and a series capacitance. Within the Operating Frequency range specified below, the assembly of Primary Coil and Shielding has a self-inductance $L_{\mathrm{P}} = 6.3^{\pm 10\%}$ μH. The value of the series capacitance is $C_{\mathrm{P}} = 0.4^{\pm 5\%}$ μF. The input voltage to the full-bridge inverter is $5^{\pm 5\%}$ V.

NOTE Near resonance, the voltage developed across the series capacitance can reach levels exceeding 100 V pk-pk.

Power Transmitter design A11a uses the Operating Frequency and duty cycle of the Power Signal in order to control the amount of power that is transferred. For this purpose, the Operating Frequency range of the full-bridge inverter is $f_{\mathrm{op}} = 110 \dots 148$ kHz. At frequencies below 148 kHz, its duty cycle is 50%, and at the frequency of 148 kHz its duty cycle is in the range of 10%…50%. A higher Operating Frequency or lower duty cycle results in the transfer of a lower amount of power.

In order to achieve a sufficiently accurate adjustment of the amount of power that is transferred, a type A11a Power Transmitter shall control the Operating Frequency with a resolution of $0.01 \times f_{\mathrm{op}} - 0.7$ kHz or better for f_{op} in the 110…148 kHz range. In addition, a type A11a Power Transmitter shall control the duty cycle of the Power Signal with a resolution of 0.1% or better.

When a type A11a Power Transmitter first applies a Power Signal (Digital Ping; see *Parts 1 and 2: Interface Definitions*), it shall use an initial Operating Frequency of 146 kHz and a duty cycle of 50%.

Control of the power transfer shall proceed using the PID algorithm, which is defined in *Parts 1 and 2: Interface Definitions*. The controlled variable $v^{(i)}$ introduced in the definition of that algorithm represents the Operating Frequency or the duty cycle. In order to guarantee sufficiently accurate power control, a type A11a Power Transmitter shall determine the amplitude of the Primary Cell current—which is equal to the Primary Coil current—with a resolution of 7 mA or better. Finally, Table 26, Table 27, and Table 28 provide the values of several parameters, which are used in the PID algorithm.

Figure 38. Electrical diagram (outline) of Power Transmitter design A11a

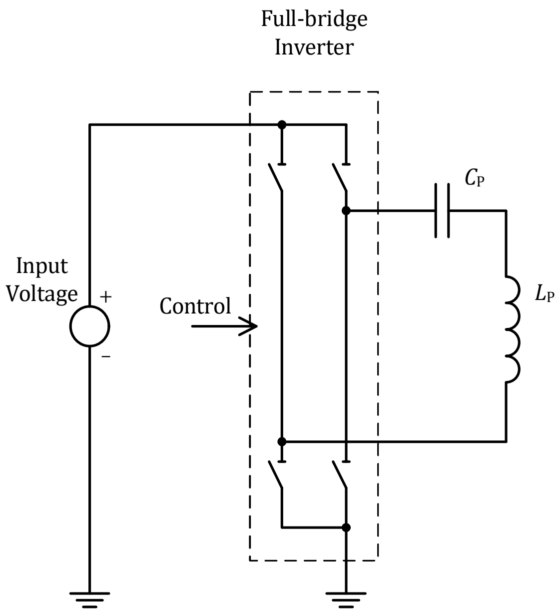


Table 26. PID parameters for Operating Frequency control

Parameter	Symbol	Value	Unit
Proportional gain	K_p	10	mA^{-1}
Integral gain	K_i	0.05	$mA^{-1}ms^{-1}$
Derivative gain	K_d	0	$mA^{-1}ms$
Integral term limit	M_I	3,000	N.A.
PID output limit	M_{PID}	20,000	N.A.

Table 27. Operating Frequency dependent scaling factor

Frequency Range [kHz]	Scaling Factor S_v [Hz]
110…140	1.5
140…148	2

Table 28. PID parameters for duty cycle control

Parameter	Symbol	Value	Unit
Proportional gain	K_{p}	10	mA^{-1}
Integral gain	K_{i}	0.05	$\mathrm{mA}^{-1}\mathrm{ms}^{-1}$
Derivative gain	K_{d}	0	$\mathrm{mA}^{-1}\mathrm{ms}$
Integral term limit	M_{I}	3,000	N.A.
PID output limit	M_{PID}	20,000	N.A.
Scaling factor	S_{v}	–0.01	%