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### Revision History: V1.0, 2010-05

**Previous Version:** none

<table>
<thead>
<tr>
<th>Page</th>
<th>Subjects (major changes since last revision)</th>
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<tbody>
<tr>
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Table of Contents

1  Introduction ........................................................................................................................................5
2  Executive Summary ...........................................................................................................................6
3  Emission Measurement Methods ....................................................................................................7
4  Emission Limit Curves ......................................................................................................................9
5  Microcontroller Operation during Test ..........................................................................................10
6  Application-Typical Emission Tests ..............................................................................................11
7  Emission caused by Pad Drivers ....................................................................................................19
8  Emission Influence from Exposed Die Pad ...................................................................................23
9  References .......................................................................................................................................26
1 Introduction

This summary describes the electromagnetic emission behaviour of the following microcontroller products:

- TC1797 in P-BGA-416 package
- TC1387 in PG-LBGA-208-4 package
- TC1782 in PG-LQFP-176-6 package

All 3 microcontrollers offer similar performance by system clock rate of 180 MHz, TriCore™ CPU and peripheral functions (e.g. FlexRay controller). The TC1797 provides in addition an external memory interface.

The 3 microcontrollers differ in their packaging and technology.

The center VSS balls of TC1797 and TC1387 are efficiently connected to the test board’s GND plane; a similar connection is provided by the TC1782 exposed die pad (e-pad).

Table 1 lists the main features.

<table>
<thead>
<tr>
<th></th>
<th>TC1797</th>
<th>TC1387</th>
<th>TC1782</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>P-BGA-416</td>
<td>PG-LBGA-208-4</td>
<td>PG-LQFP-176-6</td>
</tr>
<tr>
<td>System clock</td>
<td>180 MHz</td>
<td>180 MHz</td>
<td>180 MHz</td>
</tr>
<tr>
<td>Embedded program flash</td>
<td>2x2.0 MB</td>
<td>2x1.5 MB</td>
<td>2.5 MB</td>
</tr>
<tr>
<td>FlexRay</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>External memory interface (EBU)</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>CMOS technology node</td>
<td>130 nm</td>
<td>130 nm</td>
<td>90 nm</td>
</tr>
<tr>
<td>Core supply voltage (VDDC)</td>
<td>1.5 V</td>
<td>1.5 V</td>
<td>1.3 V</td>
</tr>
<tr>
<td>I/O supply voltage (VDDP)</td>
<td>3.3 V</td>
<td>3.3 V</td>
<td>3.3 V</td>
</tr>
</tbody>
</table>

Table 1: Comparison the main features of the microcontrollers under test.

For architectural details, please refer to the respective product specifications.

All EMI test results presented in this report are obtained from hardware and software test setups compliant to the “Generic IC EMC Test Specification” (“BISS paper”) [7], open copyright 2004 by Robert Bosch GmbH, Infineon Technologies AG, Continental AG (former Siemens-VDO).
2 Executive Summary

1) Conducted emissions of the AudoFuture and AudoMax 32-bit high-end microcontrollers TC1387 and TC1782 stay below the BISS limits for application-typical operations (i.e. all function units active and reduced pad drivers used) up to 180 MHz and thus should not cause any severe problems for low-emission PCB design.

2) Conducted emissions of the AudoFuture 32-bit high-end microcontroller TC1797 touch or slightly exceed the BISS limits especially on its power supply domains. Reason for the higher emission is its external memory bus burst interface, which makes the TC1797 more critical than the microcontrollers without external bus interface.

3) Radiated emission of the TC1387 is uncritical, while TC1797 and TC1782 touch the BISS limit in the 500-600 MHz range.

4) System clock emissions are mainly visible on the core supply domain VDDC; the core noise is efficiently decoupled from VDDP by on-chip power supply design measures.

5) I/O noise is visible on VDDP, but to a certain amount also coupled to VDDC, however it stays far below critical values.

6) I/O emission (i.e. noise propagation through inactive pads) is – in contrast to supply emission – visible up to 1 GHz. Reason is that there is no available on-chip space to design decoupling capacitors for the VDDP system. Also I/O pins can neither be decoupled on chip nor on PCB. Special care on PCB layout is advisable to prevent I/O noise from being coupled to any antenna structures on the PCB:
   a. Keep signal traces short
   b. Route signal traces as micro-strip or stripline (ground shielding)
   c. Avoid signal trace vias through power or ground planes
   d. Use lowest permissible data rates
   e. Use weakest permissible pad driver settings
   f. The TC1782 e-pad for solid grounding should be soldered to the PCB ground plane in order to keep current return paths short. It is also required for efficient power dissipation from die to PCB.

For further recommendations please refer to Infineon's application notes listed in chapter 9.

7) Conducted and radiated emissions reach the BISS limits if the strongest pad drivers are selected for high-speed signals. Generally, it is desirable to avoid high-speed signals in the application. If not avoidable, emission level from high-speed I/Os can be significantly decreased when operating I/Os at lower speed and select weaker driver strengths, as discussed above. PCB layout should be carefully considered for high-speed interface signal routing as micro-strip or stripline.
3 Emission Measurement Methods

The setup used for electromagnetic emission measurement complies fully with the BISS test specification which can be downloaded from the internet [7]. One test board was designed for every microcontroller under test with similar layout. The test board is used for conducted and radiated emission measurements.

Conducted emission is measured using the standardized 150 Ω network, see figure 1. This network is used for both port and power supply emission measurements. Only crosstalk noise is measured; i.e. the port pins under test are never actively switching. Frequency range is 150 kHz to 1 GHz.

Fig. 1 shows the schematic 150 Ω network connection to the microcontroller (IC under test) and the general layout of each 150 Ω probing net.

**Figure 1** 150 Ω probing networks for conducted emission measurement

150Ω networks are provided for conducted emission measurements according the international standard IEC 61967 part 4 and the BISS test specification for a set of signals and power supply nets. All digital power supply nets plus a subset of I/O pins (typically located in the center of all 4 package edges) are measured, see figure 2.

**Figure 2** Probed supply and signal nets for conducted emission measurement
Radiated emission is measured using the standard mini TEM cell according IEC 61967 part 2 and BISS emission test specification. The frequency range is from 150 kHz to 1 GHz.

![Figure 3 Measurement setup for radiated emission](image)

**Measurement instrumentation and conditions:**
- **Spectrum analyzer:** Rohde & Schwarz FSP7
- **Detector type:** Peak detector
- **Measurement time:** For all measurements, the emission measurement time (10ms) at one frequency is longer than the test software loop duration.
- **Pre-Amplifier:** internal
- **Data generation software:** Rohde & Schwarz EMIPAK 9950
- **Environment:** temperature 23°C ± 5°C
- **Supply:** nominal voltage ± 5%

For all measurements the noise floor is at least 6dB below the limit.

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>Spectrum Analyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RBW</strong></td>
<td><strong>Sweep time</strong></td>
</tr>
<tr>
<td>150 Ω TEM</td>
<td></td>
</tr>
<tr>
<td>150 kHz to 30 MHz</td>
<td></td>
</tr>
<tr>
<td>30 MHz to 200 MHz</td>
<td>10kHz</td>
</tr>
<tr>
<td>200 MHz to 1000 MHz</td>
<td>$t_s = \frac{NP \cdot LT \cdot FR}{RBW}$</td>
</tr>
</tbody>
</table>

*) NP = number of points; LT = loop time; FR = frequency range
4 Emission Limit Curves

For reference purpose, all measured emission spectra are enhanced by the “external digital bus systems” limit curves taken from the BISS specification [7]. Figure 4 introduces these 3 limit curves:

- Conducted emission 150 Ω, limit for supply pin emission (Supply Conducted),
- Conducted emission 150 Ω, limit for port pin emission (I/O Conducted),
- Radiated emission, limit for Mini TEM cell emission (Radiated).

![BISS limit curves in logarithmic scale](image)

If the measured emission stays below the respective limit, the measured supply or signal net is treated as “clean”. If the measured emission violates the respective limit for one or more frequencies, some more care must be taken for an EMC-friendly PCB layout. Infineon strongly recommends to use all microcontroller hardware settings provided for reduction of electromagnetic emission (as long as your required system performance permits):

- Reduce system clock frequency
- Disable unused clocks (e.g. CLKOUT, EXTCLK [automatically disabled after reset])
- Reduce output pad driver strength (up to 7 settings available for all port pins) [1] [2]
- Consider Infineon’s general and product-specific PCB design guidelines which propose optimized power supply layout and decoupling concepts [3] [4] [5] [6]
5 Microcontroller Operation during Test

To get a realistic impression of the microcontroller’s emission potential, so called “application-typical” settings have been applied during the tests. This means:

- Program execution takes place from on-chip flash memory
- CPU and all functional modules are active
- System clock output is disabled
- High-speed interfaces are active (e.g. FlexRay @ 10 Mbit/s, SPI @ 5 MBit/s, ASC / LIN / CAN @ 500 kBit/s)
- Other I/Os run at lower data rates
- FlexRay operates at 30% bus load
- TC1797 EBU burst clock operates at 20% bus load
- All output pad driver strengths are selected according their data rates, driving 22pF load. Since most pins cannot be configured individually, some more pins of the same ports are also forced to stronger state even if this would be desired only for one or two port pins. This is the ratio of driver settings (all digital outputs without ADC channels) as it was used for the emission tests:

<table>
<thead>
<tr>
<th>Driver strength</th>
<th>TC1797</th>
<th>TC1387</th>
<th>TC1782</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak</td>
<td>53 %</td>
<td>51 %</td>
<td>8 %</td>
</tr>
<tr>
<td>Medium</td>
<td>24 %</td>
<td>29 %</td>
<td>62 %</td>
</tr>
<tr>
<td>Strong-slow</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td>Strong-soft</td>
<td>14 %</td>
<td>18 %</td>
<td>29 %</td>
</tr>
<tr>
<td>Strong-medium-minus</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td>Strong-medium</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Strong-sharp-minus</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td>Strong-sharp</td>
<td>3 %</td>
<td>2 %</td>
<td>1 %</td>
</tr>
<tr>
<td>LVDS</td>
<td>6 %</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2: Pad driver scaling of the microcontrollers under test

- The power supply voltages are selected as follows:
  - \( V_{DDP} = 3.30 \) V
  - \( V_{DDC} = 1.50 \) V (TC1797, TC1387)
  - \( V_{DDC} = 1.30 \) V (TC1782)
- The system clock is 180 MHz in all cases.
- The crystal frequency is 20 MHz in all cases.
6 Application-Typical Emission Tests

General remarks:

The microcontroller is running in “application-typical” mode. The general hardware settings are described in chapter 5. Any extensive usage of strong pad drivers may significantly increase the electromagnetic emission.

Any emission peaks rising from lower noise floor in the 900-1000 MHz range may result from GSM transmitters and are not related to microcontroller operation unless they are system clock harmonics (5 * 180 MHz = 900 MHz).

In this document, only representative emission results for all power supply domains, I/O pins on each package edge (north, east, south, west) are described. The full emission measurement reports [8] [9] [10] are available upon request.

Measurements were performed on devices from center fabrication lot, operating at nominal voltages and at room temperature. Emissions are reduced for lower supply voltages and higher ambient temperature; fabrication lot influence is negligible.

The following test results are provided:

- Application-typical conducted emission on core supply net VDDC; system clock is 180 MHz.
- Application-typical conducted emission on I/O supply net VDDP; system clock is 180 MHz.
- Application-typical conducted emission on I/O net at package north edge; system clock is 180 MHz.
- Application-typical conducted emission on VDDE at package east edge; system clock is 180 MHz. ¹)
- Application-typical conducted emission on I/O net at package east edge; system clock is 180 MHz. ²)
- Application-typical conducted emission on I/O net at package south edge; system clock is 180 MHz.
- Application-typical conducted emission on I/O net at package west edge; system clock is 180 MHz.
- Application-typical radiated emission; system clock is 180 MHz.

¹) TC1797 only
²) TC1387 and TC1782 only
Application-typical conducted emission on core supply net VDDC; system clock is 180 MHz.

Figure 5  TC1797; Application; VDDC conducted; 180 MHz

Figure 6  TC1387; Application; VDDC conducted; 180 MHz

Figure 7  TC1782; Application; VDDC conducted; 180 MHz
Application-typical conducted emission on I/O supply net VDDP; system clock is 180 MHz.

**Figure 8**  TC1797; Application; VDDP conducted; 180 MHz

**Figure 9**  TC1387; Application; VDDP conducted; 180 MHz

**Figure 10**  TC1782; Application; VDDP conducted; 180 MHz
Application-typical conducted emission on I/O net at package north edge; system clock is 180 MHz.

Figure 11  TC1797; Application; P3.1 conducted; 180 MHz

Figure 12  TC1387; Application; P0.9 conducted; 180 MHz

Figure 13  TC1782; Application; P0.9 conducted; 180 MHz
Application-typical conducted emission on I/O net / VDDE at package east edge; system clock is 180 MHz.

Note: The emission behavior of TC1797 VDDE and TC1387/1782 I/O pins cannot be compared since the net characteristics are totally different!
Application-typical conducted emission on I/O net at package south edge; system clock is 180 MHz.

Figure 17  TC1797; Application; P4.9 conducted; 180 MHz

Figure 18  TC1387; Application; AN6 conducted; 180 MHz

Figure 19  TC1782; Application; AN6 conducted; 180 MHz
Application-typical conducted emission on I/O net at package west edge; system clock is 180 MHz.

Figure 20  TC1797; Application; P1.3 conducted; 180 MHz

Figure 21  TC1387; Application; P5.0 conducted; 180 MHz

Figure 22  TC1782; Application; P5.0 conducted; 180 MHz
Application-typical radiated emission; system clock is 180 MHz.

**Figure 23** TC1797; Application; radiated; 180 MHz

**Figure 24** TC1387; Application; radiated; 180 MHz

**Figure 25** TC1782; Application; radiated; 180 MHz
7 Emission caused by Pad Drivers

7.1 General Driver Impact on Emission

For emission measurements, so-called “application-typical” microcontroller configurations as described in chapter 5 are used. All function units are active, but the port pin drivers do not use their strongest default settings after reset. Instead, weaker driver settings are configured. The actual driver scaling per pin depends on the data rate this pin must provide with good signal integrity. According Table 2 in chapter 5, at least 70% of the pads are using weak and medium driver strength. These two settings do not contribute to pad switching emission and should be preferred in any application. Fast data rates recommend for strong driver settings, but even here, the microcontrollers provide several sub-settings, depending on the microcontroller family. Figure 26 provides a generic overview of emission reduction potential when weaker pad driver settings are used. The strongest driver (“strong-sharp”, default after reset) serves as the 0dB reference line. Any pad driver scaling other than “strong-sharp” leads to significant emission reduction up to 30dB (“weak”). Please note that driver settings “strong-sharp-minus”, “strong-medium-minus” and “strong-slow” are only available in the TC1782. In addition, the emission reduction numbers in dB should be treated as rough reference. The real numbers may differ. For details, please refer to the Infineon Application Notes [1] [2].

Infineon strongly recommends to use the pad driver scaling feature in order to reduce electromagnetic emission. The lists of pin-wise driver settings for the microcontrollers under test are given in the microcontroller-specific full electromagnetic emission reports which are available upon request [8] [9] [10].

If many port pins are operated using strong pad driver settings, the electromagnetic emission behavior may be worse than shown in the measurement diagrams within this document.
7.2 Emission Tests using Strongest Drivers

The following emission results have been obtained from TC1782. Deviating from the settings applied in chapter 5, all class A2 pad drivers are now operated in “strong-sharp” mode. The results can be taken as a “worst case” reference. Similar emission increase can be expected for the TC1797 and TC1387 microcontrollers.

The following test results are provided:

- Worst-case conducted emission on core supply net VDDC; system clock is 180 MHz.
- Worst-case conducted emission on I/O supply net VDDP; system clock is 180 MHz.
- Worst-case conducted emission on I/O net at package north edge; system clock is 180 MHz.
- Worst-case conducted emission on I/O net at package east edge; system clock is 180 MHz.
- Worst-case conducted emission on I/O net at package south edge; system clock is 180 MHz.
- Worst-case conducted emission on I/O net at package west edge; system clock is 180 MHz.
- Worst-case radiated emission; system clock is 180 MHz.

![TC1782 CE VDDC 180MHz WORST-CASE](image)

Figure 27 TC1782; Worst-Case; VDDC conducted; 180 MHz
Figure 28  TC1782; Worst-Case; VDDP conducted; 180 MHz

Figure 29  TC1782; Worst-Case; P0.9 conducted; 180 MHz

Figure 30  TC1782; Worst-Case; P1.7 conducted; 180 MHz
Figure 31  TC1782; Worst-Case; AN6 conducted; 180 MHz

Figure 32  TC1782; Worst-Case; P5.0 conducted; 180 MHz

Figure 33  TC1782; Worst-Case; radiated; 180 MHz
8 Emission Influence from Exposed Die Pad

Exposed die pads are used in leadframe packages to dissipate the static and dynamic IC power from the die to the PCB without need for expensive heat sinks. Typical PCB layouts use “thermal vias” to transfer the heat from the die through the PCB to the GND plane.

The TC1782 offers such an “e-pad” which is electrically connected to the VSS (ground) net of the microcontroller. Since the standard assembly forms a conducting connection between the PCB trace or plane and the e-pad, the e-pad must be soldered to the PCB GND net.

From electrical point of view the e-pad provides a lower impedance connection of all VSS supply pads on the die, because all VSS pads are bonded onto the e-pad surface. Once the e-pad is soldered to the PCB GND plane, a very low-ohmic connection between chip-GND and PCB-GND is established. The disadvantage of this configuration is the easy noise propagation from the die to the PCB. For some electrical nets, this conducting e-pad connection leads to slightly higher electromagnetic emission. On the other hand, a disconnected e-pad leads to higher dynamic voltage drop on the die during operation, thus reducing the margin for reliable operation. The electrical device specification is nevertheless fulfilled.

All emission measurement results provided in chapters 6 and 7 are obtained from TC1782 with its e-pad soldered to PCB-GND.

The following emission results are obtained from a TC1782 which was assembled in two ways: (1) e-pad soldered to PCB-GND (see result diagrams in the left column of the result table below), and (2) mounted in a socket without conducting e-pad connection (see result diagrams in the right column of the result table below). The emission of a soldered TC1782 without conducting e-pad connection will stay between any two measurement results provided in one row of the result table.

Power supply nets do not show significant differences between a soldered and an unconnected e-pad. For I/O pins, the situation is not unique, depending on the resulting current return paths.

None of the nets becomes really critical wrt. the BISS limit, neither with soldered nor with unconnected e-pad.

![Figure 34 TC1782; soldered; e-Pad; Application; VDDC conducted; 180 MHz](image1)

![Figure 35 TC1782; Socket; no e-Pad; Application; VDDC conducted; 180 MHz](image2)
Electromagnetic Emission Summary

TriCore™ High-End Derivatives TC1797, TC1387, TC1782

Figure 36 TC1782; soldered; e-Pad; Application; VDDP conducted; 180 MHz

Figure 37 TC1782; Socket; no e-Pad; Application; VDDP conducted; 180 MHz

Figure 38 TC1782; soldered; e-Pad; Application; P0.9 conducted; 180 MHz

Figure 39 TC1782; Socket; no e-Pad; Application; P0.9 conducted; 180 MHz

Figure 40 TC1782; soldered; e-Pad; Application; P1.7 conducted; 180 MHz

Figure 41 TC1782; Socket; no e-Pad; Application; P1.7 conducted; 180 MHz
Electromagnetic Emission Summary

TriCore™ High-End Derivatives TC1797, TC1387, TC1782

TC1782 CE AN6 180MHz APP

Figure 42 TC1782; soldered; e-Pad; Application; AN6 conducted; 180 MHz

TC1782 CE AN6 180MHz APP SOCKET

Figure 43 TC1782; Socket; no e-Pad; Application; AN6 conducted; 180 MHz

TC1782 CE P5.0 180MHz APP

Figure 44 TC1782; soldered; e-Pad; Application; P5.0 conducted; 180 MHz

TC1782 CE P5.0 180MHz APP SOCKET

Figure 45 TC1782; Socket; no e-Pad; Application; P5.0 conducted; 180 MHz
9 References

These documents can be downloaded from the Infineon microcontroller internet pages:

http://www.infineon.com/cms/en/product/channel.html?channel=ff80808112ab681d0112ab6b6b50805

[1] Application Note AP32111 “Scalable Pads”; Electrical Specification of Scalable Output Drivers in 130nm CMOS Technology (valid for TC1797 and TC1387)


This document can be downloaded from the ZVEI internet pages:

https://www.zvei.org/de/publikationen_veranstaltungen/publikationen_downloads/publikationen_der_fachverbaende/?no_cache=1&tx_ZVEIpubFachverbaende_pi1%5Bdownload%5D=1242&type=98


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