EZ-PD™ CCG7D consumer CLA power stage design calculator

About this document

Scope and purpose

This document provides comprehensive and easy-to-follow guidelines for the peak current mode controlled (PCMC), continuous conduction mode (CCM) cigarette lighter adaptor (CLA) power stage design calculator based on EZ-PD™ CCG7D consumer.

Intended audience

This document is intended for cigarette lighter adaptor power stage designers using the EZ-PD™ CCG7D consumer CLA power stage design calculator.

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1 Introduction

The EZ-PD™ CCG7D consumer CLA power stage design calculator is Microsoft Excel file that will calculate the power stage components for a PCMC CCM non-inverting four-switch buck-boost converter and buck only converter. Based on user inputs, the design calculator suggests components for the power stage and type 2 compensator values.

Figure 1 shows the high-level block diagram of CLA power stage. The same component designators are referenced in the *EZ-PD™ CCG7D consumer CLA power stage design calculator.xlsx (see 002-33977.xlsx)* file available with this document.

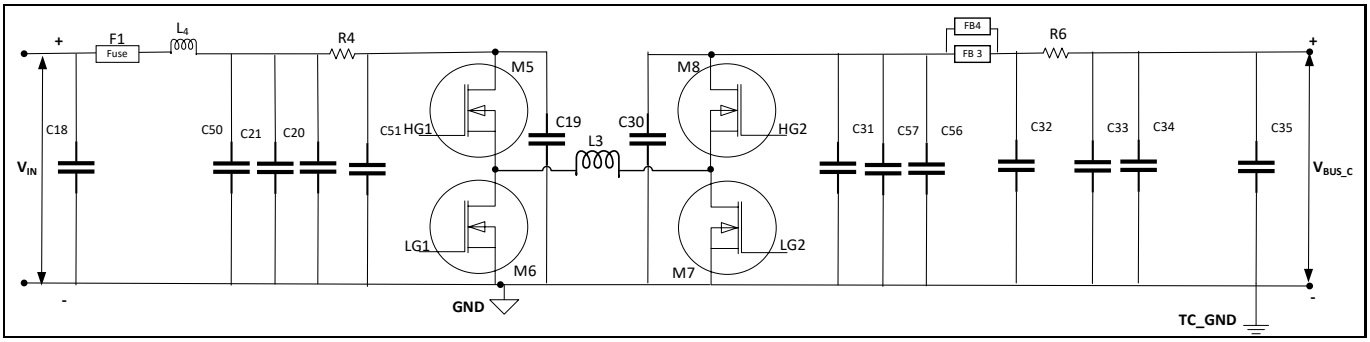


Figure 1 High-level block diagram of CLA power stage

Figure 2 shows the type 2 compensator for port #0 used in the CLA solution board. The same component designators are referenced in the *EZ-PD™ CCG7D consumer CLA power stage design calculator.xlsx (see 002-33977.xlsx)* file available with this document.

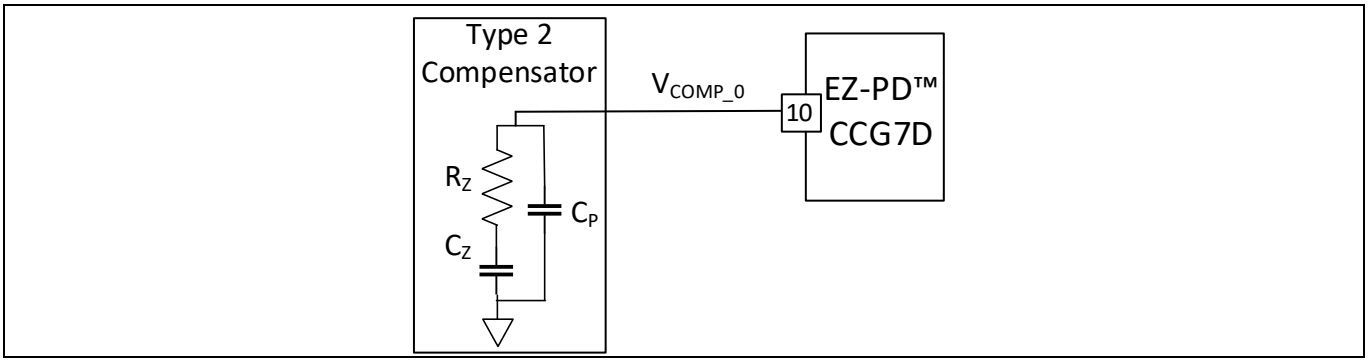


Figure 2 Type 2 compensator – port #0

2 EZ-PD™ CCG7D consumer and CLA solution board - General description

EZ-PD™ CCG7D consumer is highly integrated dual-port USB Type-C Power Delivery (PD) solution with integrated buck-boost controllers. It complies to the latest USB Type-C and PD specifications, and is targeted for automotive charger applications such as head-unit charger, rear seat chargers and rear seat entertainment. Integration offered by EZ-PD™ CCG7D consumer not only reduces the bill of materials (BOM) but also provides a footprint optimized solution for automotive charging needs. EZ-PD™ CCG7D consumer has integrated gate drivers for VBUS NFET on the provider path. It also includes hardware-controlled protection features on the VBUS. EZ-PD™ CCG7D consumer supports a wide input voltage range (4 V-24 V with 40 V tolerance) and programmable switching frequency (150 kHz – 600 kHz) in an integrated PD solution.

EZ-PD™ CCG7D consumer is the most programmable USB PD solution with on-chip 32-bit Arm® Cortex®-M0 processor, 128KB flash, 16KB RAM, and 32KB ROM that leaves most flash available for user application. It also includes various analog and digital peripherals such as ADC, PWMs, and timers. The inclusion of a fully programmable MCU with analog and digital peripherals allows the implementation of custom system management functions such as power throttling, load sharing, temperature monitoring, and black box.

The USB PD CLA solution board needs to deliver a wide range of configured positive output voltage and power from a 12 V nominal automotive battery. A four-switch buck-boost converter (FSBBC) is the suitable topology, which can support variable input voltages and configurable output voltage applications such as USB PD where high efficiency and power density is also required. The FSBBC configuration can act as buck, boost, or buck-boost converter to provide output voltage with the same polarity of the input voltage. Improved efficiency of the FSBBC is observed due to synchronous rectification. In similar lines, buck only and boost only operation can be achieved. Constant-frequency PCMC is a popular control technique for switched-mode power converters. PCMC offers built-in overcurrent protection, robust dynamic responses, simplified voltage-loop compensator design, and rejection of input voltage disturbances.

3 Features of EZ-PD™ CCG7D consumer CLA power stage design calculator

The EZ-PD™ CCG7D consumer CLA power stage design calculator allows you to choose the power stage and type 2 compensator components for a PCMC CCM non-inverting four switch buck-boost converter and buck converters.

The power stage design calculator is based on CCM power stage of:

- PCMC non-inverting four-switch buck-boost converter topology
- PCMC synchronous buck converter topology

The inputs to the calculator include:

- Design inputs:
  - Operating input voltage range (V_{IN})
  - Configurable output voltages (V_{BUS_C})
  - Load current (I_{OUT})
  - Nominal switching frequency of the power converter (F_{SW})
- Converter performance parameters:
  - Input voltage transients due to change in load conditions ($V_{INTransient}$)
  - Input voltage ripple ($V_{INRipple}$)
  - Output voltage transients due to change in load conditions ($V_{OUTTransient}$)
  - Output voltage ripple ($V_{OUTRipple}$)
  - Load step ($I_{OutTransient}$)
- Control loop and EMI filter parameters:
  - Buck converter control loop cross over frequency (F_{C_Buck})
  - Boost converter control loop cross over frequency (F_{C_Boost})
  - Bandwidth of input LC EMI filter ($F_{BW_IP_EMI_LC}$)

Note: *The crossover frequency, in a buck converter, can be one-tenth of the chosen switching frequency. In a boost converter, the crossover frequency can be less than one-tenth of the switching frequency and less than one-fifth the right half plane (RHP) zero frequency, whichever is lower.*

This design calculator provides design guidance for the following:

- Power stage components:
  - Power inductor (L)
  - Input bulk capacitor (C_{IP_Bulk})
  - Output bulk Capacitor (C_{OUT_Bulk})
  - Power MOSFETs (M5-M8)
  - Input EMI LC filter inductor (L_{EMI})
  - Input MLCC @ EMI filter (C_{EMI_MLCC})
  - Input MLCC @ input bulk capacitor (C_{IP_MLCC})
  - Output MLCC @ output bulk capacitor (C_{OUT_MLCC})

Features of EZ-PD™ CCG7D consumer CLA power stage design calculator

- Type 2 compensator components:
  - Compensator resistor (Rz)
  - Compensator capacitor (Cz)
  - Compensator capacitor (C_P)

Note: *The calculated type 2 compensator (Rz, Cz, and Cp) values are based on the selected buck converter crossover frequency referenced in the design calculator - cross over frequency-rbuck (F_{C_Buck}).*

The design calculator provides the following converter performance parameters for the provided inputs:

- Input voltage transients due to change in load conditions ($V_{INTransient_Calc}$)
- Input voltage ripple ($V_{INRipple_Calc}$)
- Output voltage transients due to change in load conditions ($V_{OUTTransient_Calc}$)
- Output voltage ripple ($V_{OUTRipple_Calc}$)
- Bandwidth of input LC EMI filter ($F_{BW_IP_EMI_LC_Calc}$)

This design calculator provides the following plots and graphs for the entered values:

- Efficiency graphs of the converter in buck mode operation (CCM)
- Efficiency graphs of the converter in boost mode operation (CCM)
- Bode plots of the buck converter
- Bode plots of the boost converter

4 Usage model of EZ-PD™ CCG7D consumer CLA power stage design calculator

This section discusses on the usage model of the EZ-PD™ CCG7D consumer CLA power stage design calculator.

EZ-PD™ CCG7D consumer CLA power stage design calculator is Microsoft Excel file with the following worksheets:

- About the calculator: Includes basic information about the EZ-PD™ CCG7D consumer CLA power stage design calculator
- Home page: Allows you to provide design inputs for the power stage and compensator values for the chosen topology
- Efficiency buck mode: Displays the efficiency graphs of buck converter for the chosen inputs
- Efficiency boost mode: Displays the efficiency graphs of boost converter for the chosen inputs
- Buck mode - CV_Bode plot: Displays the peak buck converter plant, compensator, and loop gain plots
- Boost mode - CV_Bode plot: Displays the peak boost converter plant, compensator and loop gain plots
- Designers recipe – Lists the EZ-PD™ CCG7D consumer silicon parameters, which must be validated. Note that only Infineon representatives can modify the parameters.

The Home page of the EZ-PD™ CCG7D consumer CLA power stage design calculator has the following sections:

Note: In the Home page, you can provide the design inputs in the fields marked blu( ) and observe the design outputs in the fields marked ( ).

- Section 1 - Design inputs: Allows you to provide the design inputs and select the topology. By default, peak current mode controlled continuous current mode non-inverting buck – boost converter power stage components are displayed, and when you select **Buck** from **Topology Selection**, peak current mode controlled continuous current mode buck converter power stage components will be displayed.
- Section 2 - Power components - Computed values: Displays the calculated values for the selected topology and design inputs. Based on the values, you can choose either the off-the-shelf or custom parts.
- Section 3 - Type 2 compensator computed values and type 2 compensator - User chosen values: Provides guidance on type 2 compensator RC values, and has the option to plug in components available off-the-shelf. The bode plots in the worksheets buck mode - CV_Bode plot and boost mode - CV_Bode plot are based on the plugged-in values.
- Section 4 - Power components: From the guidance values computed in the section 2, choose the off-the-shelf components and enter their characteristics. The efficiency graphs and bode plots are derived based on the selected components and their characteristics.
- Section 5 - Design output for the user chosen components: Provides the performance of the power stage for the components selected in section 4
- Section 6 - Plots/graphs for the user chosen values: Displays efficiency graphs and bode plots for the components selected in the section 4.

Note: The maximum allowed duty cycle in the buck topology is 90% for practical purposes. Keep this in mind while choosing the required V_{BUS_C} voltage for a given input voltage.

References

[1] 002-33978- Hardware design guidelines for EZ-PD™ CCG7D consumer in cigarette lighter adaptor applications

Revision history

Document version	Date of release	Description of changes
**	2021-09-15	Initial release

Note: *The EZ-PD™ CCG7D consumer CLA power stage design calculator excel file is submitted as source file (see 002-33977.xlsx) along with this user guide.*

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