

# Automation of AC-DC Power Adapter Validation

<sup>1</sup>Manvi Gupta, <sup>2</sup>Dr Neelu Jain

<sup>1</sup>M.E. Electronics Student, <sup>2</sup>Professor and Head

Electronics and Communication Engineering Department

Punjab Engineering College (Deemed to be University), Chandigarh, India

**Abstract:** In this paper, a new automation method is proposed for the validation of AC-DC power adapters. Validation phase is very crucial before any product is launched in the electronics world. Various tests need to be done for similar conditions, thus repeatability and reliability are important. Being more prone to errors, doing these tests manually requires a lot of time and manual effort. Thus, an efficient and reliable automation system is developed using LabVIEW tool covering the test cases. The AC-DC adapter used here is EZ-PD CCG3PA mobile power adapter using Diode's controller since it is based on flyback converter. After a brief overview of the adapter being used, the automation experiments performed and results have been presented. Finally, comparing automation and manual testing time reveals that 3 man-weeks are saved in automation.

**Index Terms:** AC-DC power adapter, flyback converter, LabVIEW, CCG3PA

## I. INTRODUCTION

During the validation phase of any electronic device (which is Type C AC-DC power adapter in our case), various experiments must be performed before it is finally launched as a product in the market for customers to use. They may also include doing similar tests for various line and load conditions. These kinds of tests consume lot of man-hours if done manually, which leads to the need of an automation system which can perform all tests by itself with negligible human intervention.

This paper discusses about development of an automation system for the post-silicon validation of a power adapter based on USB Type C controller, after a brief overview of the Type C AC-DC power adapter being used. This controller (CCG3PA [1]) is targeted for solutions/applications like Power Adapter, Car chargers and Power Banks across various platforms. The impetus of taking Type C is its reversible design, 100W (20V, 5A) power delivery capability, single connector which can be used in notebook computers, tablets and mobile phones, moreover USB-C has identical connector for both host and peripheral [2]. The power adapter being used is CCG3PA 27W mobile power adapter, which has mainly three components; Diodes's AP3302A [9] (offering Quasi resonant PWM switching control, acting as primary controller), Diodes's APR345 [10] (Synchronous Rectification Controller) and the CCG3PA (PD controller acting as the secondary controller).

Structuring of the paper is done as described. Section 2 discusses about the SMPS in general and the most suitable SMPS converter topology for our power adapter. Section 3 gives a concise overview of the CCG3PA controller. In section 4, the LabVIEW and hardware setup is explored proceeding to the experimental results from LabVIEW in Section 5. The paper gives its conclusion in Section 6.

## II. POWER SUPPLIES

Being a prerequisite component of several electronic equipments, power supplies generally utilize ac voltages as primary source which should be transformed to dc voltages. The regulated power supplies can be classified as linear and switched-mode (SMPS) [11]. The linear once always conducts current and are employed where there is requirement of less noise and ripple; whereas in SMPS a series element is switched on and off uninterruptedly to keep output voltage ( $V_{out}$ ) within prescribed limits. SMPS has superiority in terms of size. The regulation in linear supply is done by a voltage regulator which has ohmic losses making it less efficient. Whereas, a feedback circuitry implements voltage regulation in the other type, as presented in **Fig.1**. This feedback circuit's input in SMPS comes from  $V_{out}$  (DC output voltage) and feedback's output is advanced to PWM control circuitry, which further initiates the gate pulse generation relative to DC output. SMPS's are henceforth admired for enhanced efficiency and power density results. Thus, SMPS is used in the AC-DC adapter used for automation here.

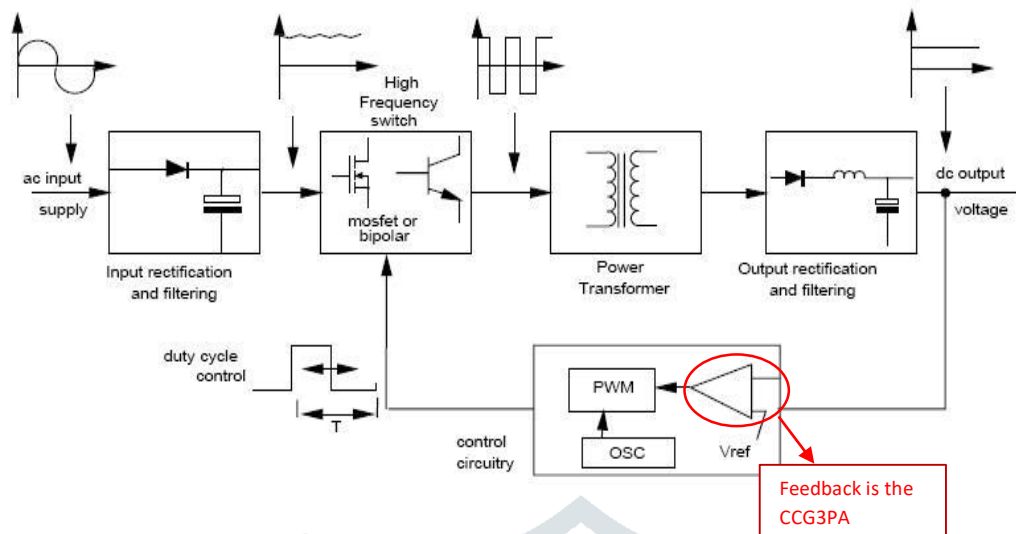


Fig.1 SMPS block diagram showing CCG3PA in feedback [11]

In past, several converter topologies have been proposed for SMPS, but flyback is the best one for low power applications (150W) with low standby power, broad input voltage range and the design being simple [4] [5]. They have capability to produce a DC output from either a DC or AC input. It uses mutually coupled inductors to first store energy when current passes through primary and then releasing energy when primary is non-conducting and the secondary conducts.

Following are the features of flyback converters:

- Coupled Inductor design is simple for low power applications
- Low component number leads to lower cost
- Can provide multiple outputs, each being isolated from one other [6]
- Capable of supplying equal or different output powers in each stage
- Galvanic Isolation, i.e., isolation (electrical and physical) between output and input circuits
- Provides high output voltages and thus high efficiency

Both windings in a such a topology are exploited as two separate magnetically coupled inductors with opposite polarity, thus simultaneously, both windings can't carry current. This proves as an advantage in cases where dc output and ac input supply have to be isolated from each other. Hence, when the primary FET (switch) is off, only then can energy be transmitted to the secondary.

$V_{out}$  is controlled by a closed loop control circuit here. It is maintained within a tolerable band around required  $V_{out}$  with the help of CCG3PA which modulates the switch's duty ratio. This duty ratio is managed by PWM control circuit.

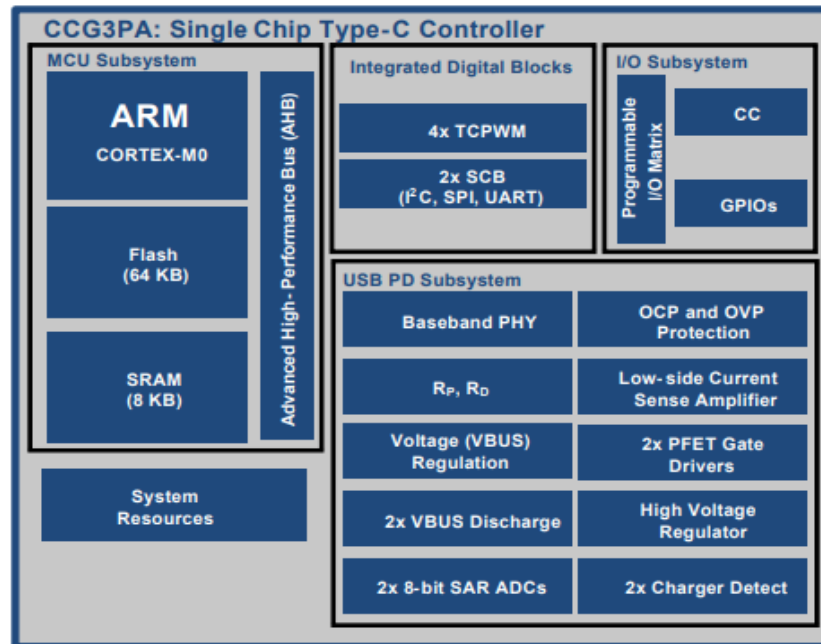
### III. TYPE-C CONTROLLER CCG3PA

EZ-PD CCG3PA (which stands for Easy-Power Delivery Type-C Controller Generation 3 for Power Adapter) [3] owned by Cypress's family of USB Type-C controllers suffices to the latest USB-C and PD standards.

Following are the attributes of CCG3PA controller:

- Consists of an ARM Cortex-M0 at 48MHz, 64KB flash, 8KB SRAM, 12 GPIOs, Type-C/PD Baseband transceiver
- Inbuilt protections like Over Voltage (OVP), Under Voltage (UVP), Over Current (OCP) and Under Current (UCP), Over temperature
- Supports one USB-C and one USB-A port
- 3V to 24.5V operation
- 24 pin QFN and 16 pin SOIC package
- Integrated error amplifier for secondary side control

Following is the block diagram for CCG3PA chip showing major internal blocks used:



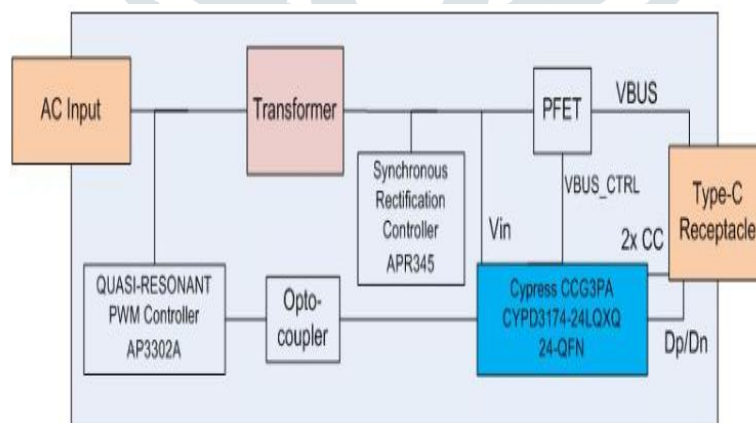
**Fig.2** Internal block diagram of CCG3PA [1]

Major applications of CCG3PA are power adapters of mobile and PC, car charger and power banks. These solutions consist of port controller and power plant (or regulator). The chip (CCG3PA) acts as port controller in the above-mentioned solutions. Thus, it will be responsible for handling the power negotiations over USB-C connector and for controlling the regulator's output power or voltage using a suitable feedback output. To control the Vout, Power Plants use various technologies; e.g. AC-DC controller makes use of the direct feedback input whereas flyback converters use opto-isolators.

Some of the CCG3PA solutions are:

1. PC Power adapter with Opto-isolator feedback control
2. Mobile phone power adapters with direct feedback control
3. Car Chargers (CLA)
4. Power Bank (portable external battery solution)

**Fig.3** shows the simplified block diagram for the complete CCG3PA+Diodes power adapter:

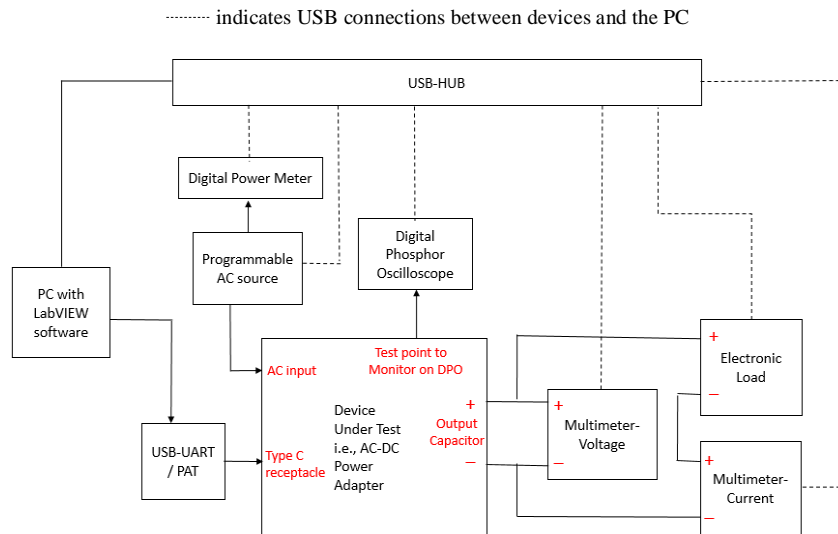


**Fig.3** Block Diagram of CCG3PA+Diodes adapter solution [8]

As mentioned earlier the adapter solution has mainly three components: AP3302A [9], APR345 [10] and CCG3PA. The CYPD3184-24LQXQ tracks the Data positive (Dp), Data negative (Dn) and two CC lines; deciphers required voltage and current conditions according to PD protocol, and subsequently imparts the feedback details to Quasi resonant controller for regulation of VBUS. The external PFET is driven by CYPD3174. Optocoupler feedback is used in this 24pin QFN package.

## IV. LABVIEW GUI DEVELOPMENT

LabVIEW is selected for the automation of validation for the power adapter because of several advantages. It has a modular design, can do parallel processing and the ease of interfacing with instruments. The subsequent **Fig.4** demonstrates the block diagram of the hardware setup being used for validation.



**Fig.4** Block Diagram of hardware setup used

The CCG3PA + Diodes adapter board has a USB Type C connector as discussed previously. There are two methods to make the PD contract with it. One is through USB to UART serial communication, and the other one is USBCEE's PAT (Power Adapter Tester) which directly connects to the adapter's Type C receptacle. PAT is generally exploited to troubleshoot and validate USB-C power adapters [7]. The PAT GUI demonstrates the abilities of adapter (PDOs).

#### OVERALL SETUP WORKING PROCEDURE:

When the LabVIEW project is first run, it initializes all the connected instruments to default values set while development of code. The GUI initially presents the list of various tests which have been automated. User needs to select the test of interest. The common DUT (Device Under Test) parameters which must be set by user for all tests are input AC voltage, input frequency, DUT Vout, option to choose UART or PAT for PD contract, DUT load, oscilloscope settings among others. After the user provides necessary inputs for the respective test, RUN button is hit and the test starts. The data is captured simultaneously, i.e., LabVIEW reads values from the instruments connected and a table mentioned in the GUI gets filled with subsequent data. The waveforms (if any) are captured and saved during the test. After the test is over, the user has an option of whether to save the results in an excel format or not. If the user forgets to save the data, a warning comes if the tab is changed or closed. Then the user can proceed with the next test.

#### V. EXPERIMENTAL RESULTS

Succeeding is explanation for various test cases covered along with their results.

##### 1. Steady State Efficiency:

Output efficiency data is calculated in this test. The GUI has an option for warmup at  $V_{in}=265V_{ac}$ , 63Hz,  $V_{out}=11V$ ,  $I_{out}=3A$ . The test takes data for the various conditions changing automatically and saving the report with plots.

Conditions:

- AC line = 85Vac, 115Vac, 230Vac, 265Vac
- Line frequency = 47Hz, 50Hz, 60Hz, 63Hz
- $V_{out}$  = 3.3V, 5V, 9V, 11V
- $I_{out}$  (Load) = 10%, 25%, 50%, 75%, 100% (of 3A)

Following figure shows 4 plots for Efficiency vs Load% at  $V_{out}$  = 3.3V, 5V, 9V and 11V; Line=115Vac, 60Hz.

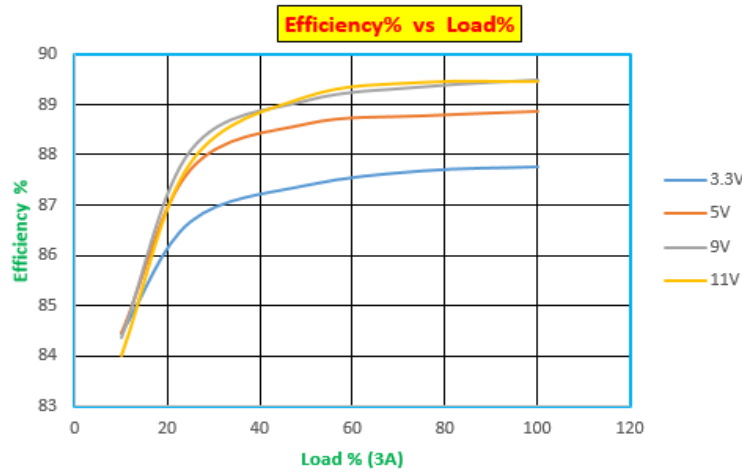


Fig.5 Efficiency vs load plot at 115Vac, 60Hz Line

2. Steady State CV-CC Regulation:

The CV-CC curve is obtained from this test. Each of the four Vout values are checked across CC limits of 1A, 2A and 3A. CV-CC curves for each condition mentioned are shown in Fig.6 This plot shows the Vout changes with load in the CV and CC regions.

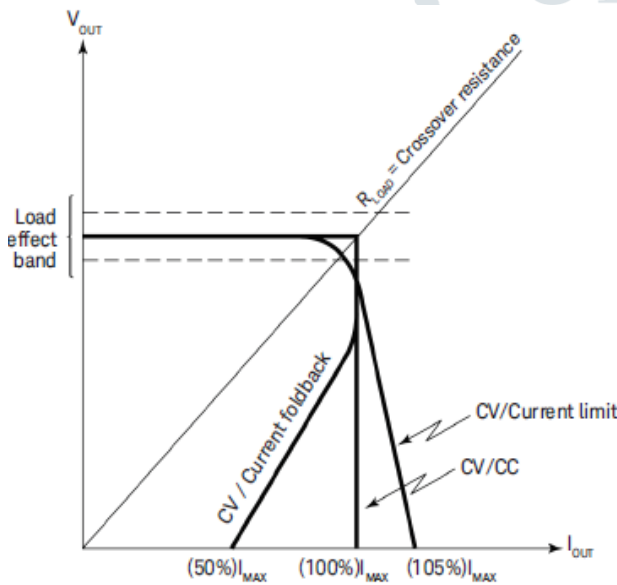


Fig.7 CV CC curve of a typical power adapter

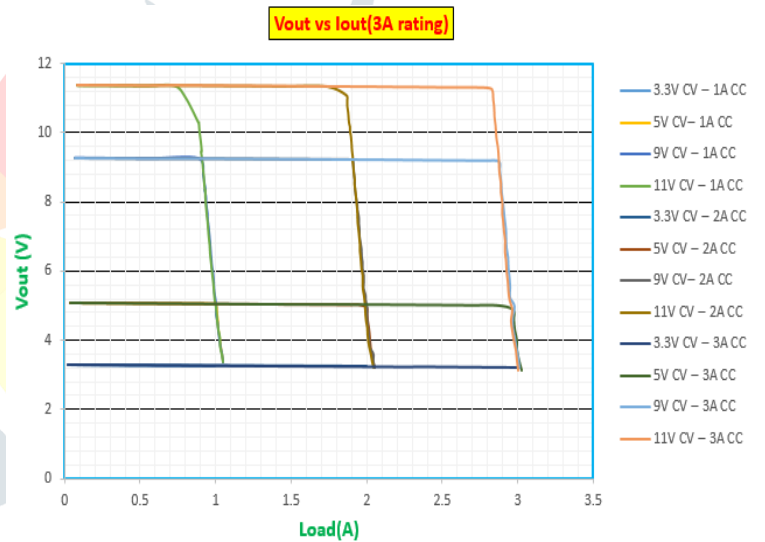


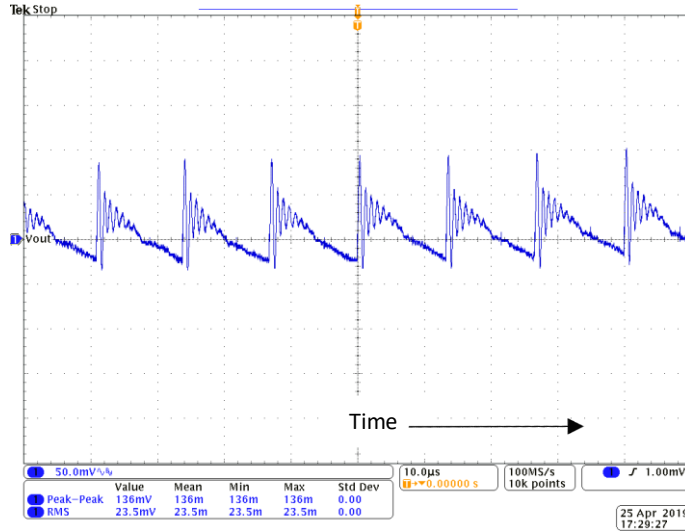
Fig.6 CV-CC curve at 115Vac, 60Hz line

There are two regions in Vout vs Iout curve for any adapter: CV and CC. In the CV region, secondary controller regulates the Vout as per the PD contract. Hence for a good adapter, Vout should be within 3% error in CV region as the load grows, and this is visible in the Fig.6 as a nearly straight horizontal line in CV region. In the CC region, the CC limit is set (1A, 2A, 3A in our case). As the load escalates beyond this CC limit, to maintain constant power the Vout decreases, depicted in Fig.6. Thus, now the current is regulated in this region and the vertical curves indicate this behavior. The CV-CC curve of a typical power adapter is shown in Fig. 7.



3. Steady State Ripple:

Here the user gets to know the ripple at the Type C end. In this custom test, user can check the Type C ripple at any line and Vout condition. User has to provide the minimum load, the maximum load, along with oscilloscope settings. The test starts capturing data and ripple waveform for the mentioned condition starting from minimum load and then goes to 25%, 50%, 75% and 100% of maximum load mentioned by user. Efficiency for the data is also calculated along with peak-to-peak ripple. Thus, this test can be used to calculate efficiency for custom line and Vout condition as compared to the complete SS Efficiency run. **Fig. 8** is an example of one of the ripple waveforms captured by LabVIEW during this test.

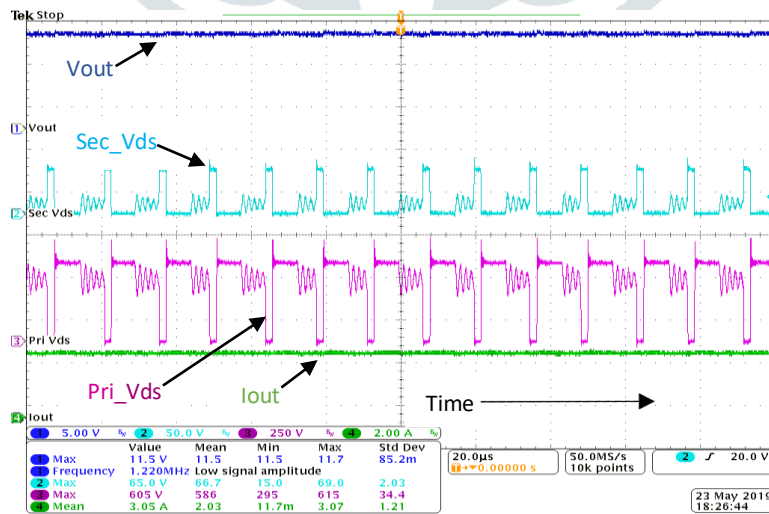


**Fig.8** Output Voltage Ripple at 115Vac, 11Vdc, 3A load showing  $V_{\text{peak-to-peak ripple}} = 136\text{mV}$

4. Steady State Drain Capture:

This GUI is majorly utilized to monitor the Primary and Secondary MOSFET’s drain-source voltage waveforms to observe the switch voltage stress. Four signals can be monitored in this test. Custom line, Vout, min load and full load values can be selected by user, and the result together with waveforms is captured for min load, 50% and 100% of rated load. Frequency of a signal connected to one of the channels is also measured. There is an option to select which measurement function has to be used for the 4 channels of the oscilloscope.

Below is **Fig.9** which shows one such example making use of 4 channels for Vout, Iout, Sec\_Vds (Drain-Source voltage of secondary FET) and Pri\_Vds (Drain-Source voltage of primary FET).



**Fig.9** Drain Capture (at 265Vac, 63Hz, Vout=11V, Iout=3A, CH1=Vout, CH2= Sec\_Vds, CH3=Pri\_Vds, CH4=Iout) w.r.t time

### 5. CV-CC Custom Regulation:

This can be utilized when the custom line CV-CC regulation is of interest rather than the full suite as described in Test#2. The regulation error is calculated in the GUI. In CV region, regulation is measure as follows:

- Voltage Regulation Error% = (Nominal Voltage - Vout)/Nominal Voltage \* 100

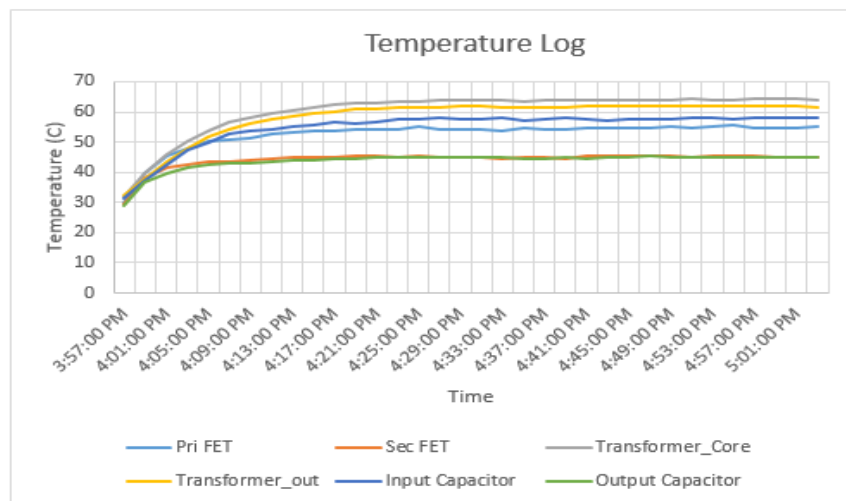
Nominal voltage to be provided by the user (takes Vout value by default).

- Current Regulation Error% = (Nominal Current - Iout)/Nominal Current \* 100

Nominal Current to be provided by the user (takes Iout value by default).

### 6. Thermal Log:

During validation phase of the adapter, it is extremely crucial to keep a track of temperatures of various components over time, so that temperature doesn't exceed the USB spec limits even at the extreme conditions. This GUI can observe and then log the temperature of various components wherever the thermocouple is attached. This can be done at any line and load conditions as required by the user. A timer can be set for the test span or user can also manually stop the test as per the requirement. When the test is over, a thermal log is saved along with a plot of Temperature vs Time indicating thermocouple name and number. **Fig.10** shows an example at Line=85Vac, Vout=11Vdc and Load=3A.



**Fig.10** Plot for temperature of 6 components over time (1hr)

### 7. CV Load Transient:

This tests for Vout dynamic response in CV region with load transients. Whenever an adapter is directly plugged in the wall, it means that a high load is directly applied. So, the Vout response to load transients (e.g., 0.3A to 3A and vice-versa) should not have very high undershoots or overshoots. The settling time should also be within limits. This test case helps in observing this behavior.

The GUI has the extra options mentioned below:

- Startup and final current for load transient
- Rise and fall slew rates
- On and off time of the load current pulse

Continuous pulses of load current are sent according to parameters set by user in the GUI, which is monitored on one channel of DSO. We can observe the corresponding change in Vout (AC coupling) and find out the Vout settling time, undershoot in addition to overshoot. Given below is an example.

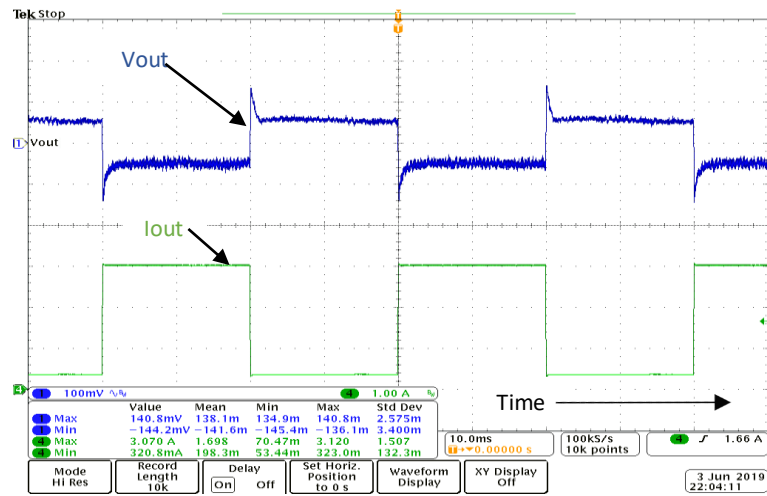


Fig.11 CV load transient (115Vac, 5V, 0.3A to 3A) w.r.t time

### 8. Iout Dynamic Response:

This test describes transients in the CC region as compared to that of CV region in previous case. This means that there is load step applied being in CC region. This step value is provided in the form of start and stop resistance (calculated according to Vout and Iout required) by user in the GUI. In this manner, we are starting in CC region and going to deep CC region or vice-versa. Vout (in AC coupling of oscilloscope) is monitored and captured during these transitions.

The GUI has the extra options mentioned as follows:

- Startup and final resistance values for transient
- Rise and fall slew rates
- Channel coupling (AC or DC)
- Trigger option to capture oscilloscope waveform
- External Trigger option in which different trigger can be set for rising and falling edges
- The Fig12 shows one such example. The undershoot in Iout and overshoot in Vout can clearly be observed while we make a load change being in CC mode.

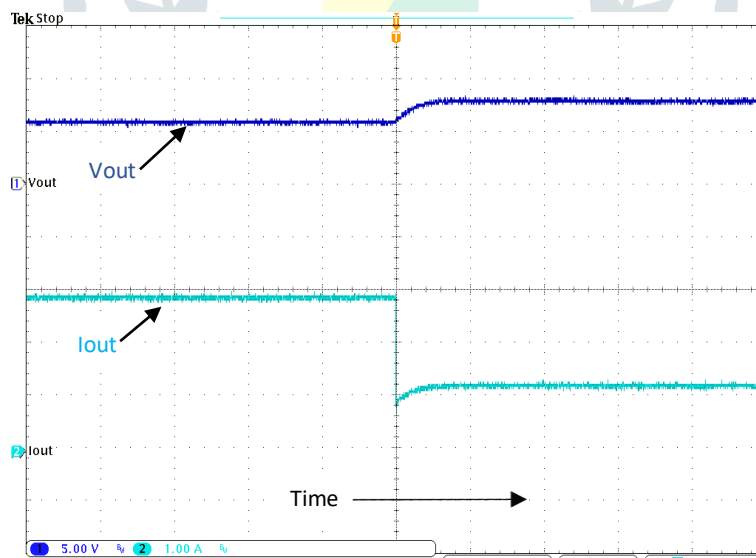


Fig.12 Iout Dynamic response (230Vac, 50Hz, Vout=9V, CC limit=1.5A, Iout step= 2.9A to 1.5A) w.r.t. time

## VI. CONCLUSION

In this paper, a new automation system was proposed for the validation of AC-DC power adapters. Adapter used for this automation was Cypress's CCG3PA USB-C mobile power adapter using Diode's SR controller APR345. This automation was done using LabVIEW tool which covers several test cases to be done during the validation phase before any product is launched in the market for customers to use. Every test covered had a separate GUI for it, which could be chosen from the main GUI. All the parameters were



provided in the GUI for the user to change and experiment accordingly. The result data and waveforms were also saved automatically respective to the test.

Total test time with manual validation	6.5 manweeks
Total test time with automation validation	3.7 manweeks

**Table 1:** Comparison between automation and manual time

Comparison of manual versus automation times shows a reduction of around 3 man weeks (8hr man-day).

The main advantages of using an automation system was saving huge time during manual validation and reducing the human error while measurement.

## VII. REFERENCES

- [1] Cypress Semiconductors, “EZ-PD CCG3PA Datasheet: USB Type C Port Controller”, March 2018. [Online]. Available: <https://www.cypress.com/file/363381/download>
- [2] S.E. Liu *et al.* “Type C Interface Reliability concern of electrical overstress and design for mitigation”, *IEEE International Reliability Physics Symposium*, 2017
- [3] Application Note AN218179 – Getting started with EZ-PD CCG3PA, <https://www.cypress.com/file/363656/download>
- [4] Nasir Coruh *et al.*, “Design and Implementation of Flyback Converters”, 5<sup>th</sup> IEEE Conference on Industrial Electronics and Applications, 2010, pages 1189-1193
- [5] Qiang Wu, Zhangming Zhu, “An Adaptive High Precision OCP control Scheme for Flyback AC/DC Adapters”, *IEEE Transactions on Power Electronics*, 2017, Vol 32, Issue 12, Pages: 8969-8973
- [6] Agasthya Ayachit, Alberto R., Marian K. K., “Magnetising Inductance of multiple-output flyback DC-DC converter for discontinuous conduction mode”, *IEEE – IET Power Electronics Journal*, 2017, Vol.10, Iss. 4, pp. 451-461
- [7] USBCEE. “CCPROG PAT: USB-C Power Adapter Programmer and Tester” [Online]. Available: <https://usbcee.com/product-details/3>
- [8] Cypress Semiconductors, “EZ-PD CCG3PA USB-C Mobile Power Adapter using Diodes”, May 2018. [Online] Available: <https://www.cypress.com/documentation/reference-designs/ez-pd-ccg3pa-usb-c-mobile-power-adapter-solution-using-diodes#res575>
- [9] Diodes Incorporated, “Quasi-Resonant PWM Controller AP3302 Datasheet”, March 2017. [Online] Available: <https://www.diodes.com/assets/Datasheets/AP3302.pdf>
- [10] Diodes Incorporated, “Secondary Side Synchronous Rectification Controller APR345 Datasheet”, June 2016. [Online] Available: <https://www.diodes.com/assets/Datasheets/APR345.pdf>
- [11] Hazel Grove, ‘Switch Mode Power Supplies, Power Semiconductor Applications’, Application note, Philips semiconductors, pp.107