Power Battery Charger Calibration Fixture Application Note

D/N: AN0471E

Introduction

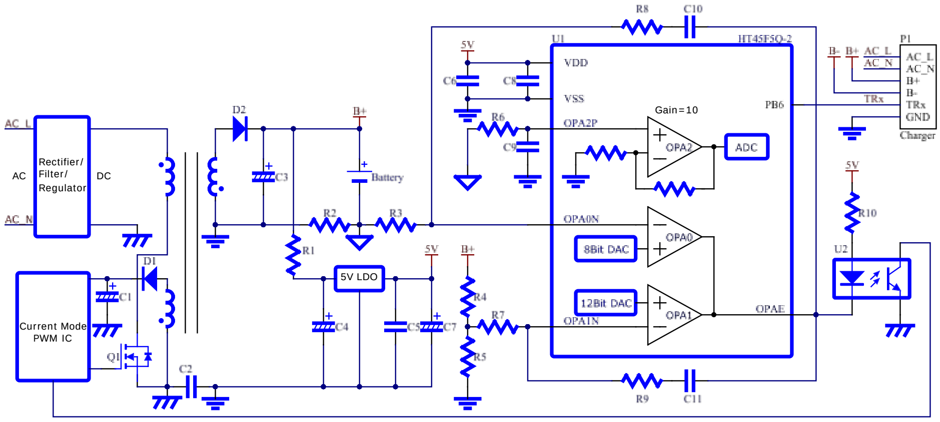
Power chargers for electric bicycles, electric motorcycles and power tools, etc., are all calibrated before delivery, thereby correcting any charging parameter drifts due to external component tolerances. This will ensure the output voltage and current conform to their specifications. However, traditional applications are calibrated manually in production by using variable resistors, which reduces production efficiency as well as increasing manpower, thus increasing manufacturing costs.

Holtek's charger ASSP MCUs, the HT45F5Q, HT45F5Q-2 and HT45F5R, are all integrated with a battery charge module and an EEPROM. By using an automatic calibration fixture, both the charger output voltage and current can be corrected and the calibration parameters can also be written into the EEPROM. This application note takes the HT66F70A device as an example MCU for the calibration fixture to illustrate how to calibrate the HOLTEK charger ASSP MCU automatically. Users can adapt this example to design their own calibration fixture.

Functional Description

Charger Calibration Reasons and Principles

During the charger mass production process, the actual output voltage or current may exceed the acceptable error range due to component tolerances such as R2~R8, C6, C7 and U2 or for other reasons. The Holtek charger ASSP MCU includes an integrated battery charger module. Adjusting the internal D/A converter will change the optical coupling primary side current, and therefore the PWM IC output, to achieve adjustments in output power. When the charger is powered on, the MCU will first check the connection status with the fixture to determine whether to enter the calibration mode. If successful, the calibration process will be initiated, and the calibration values will be stored in the EEPROM. After this, each time the charger is powered on, the MCU will load the updated calibration values from the EEPROM for correction purposes.

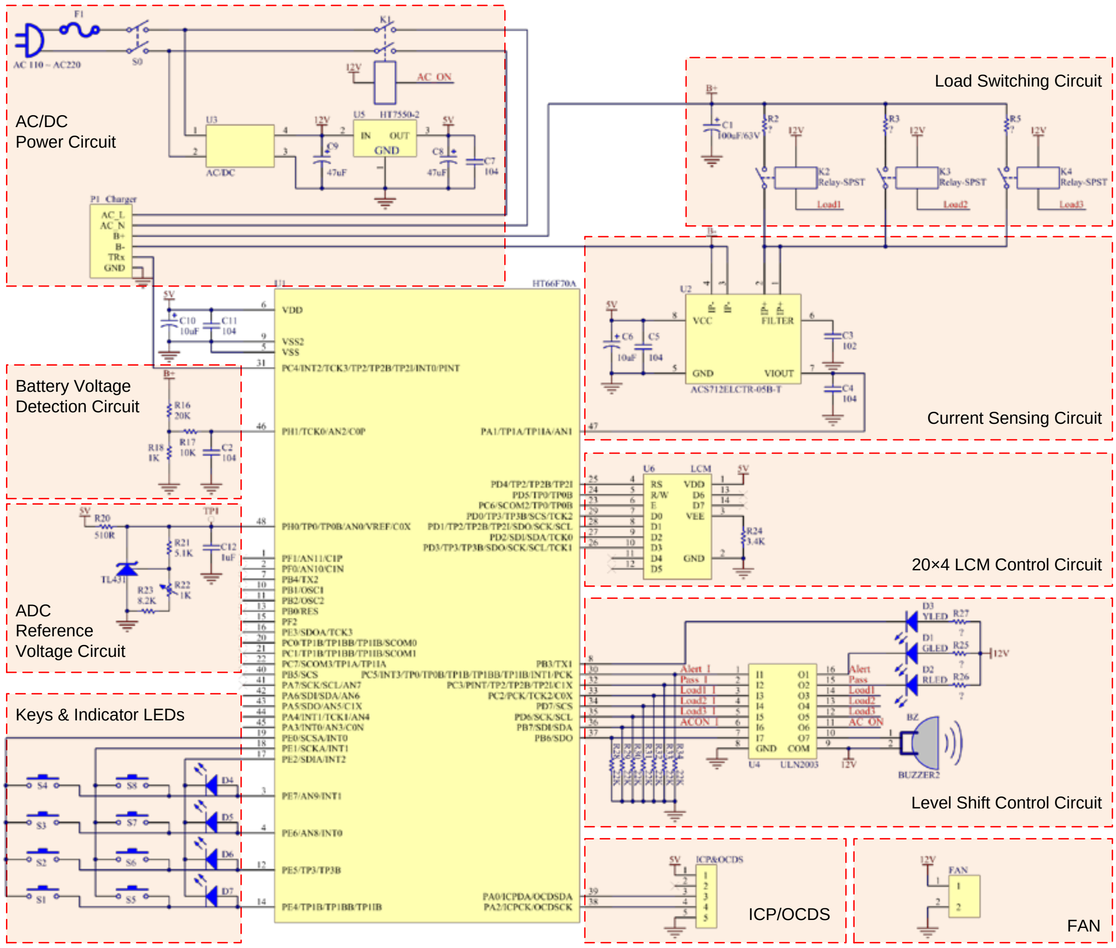


HT45F5Q-2 Charger Application Circuit

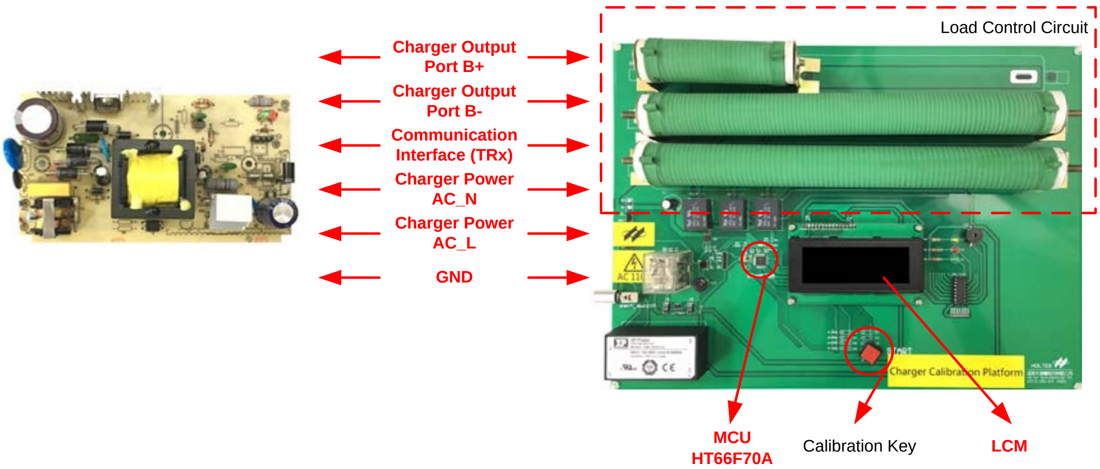
Hardware Description

In order to ensure the fixture precision, an external TL431 (±0.5%) is used as the MCU A/D reference voltage, V_{REF}. A variable resistor, R22, is also added, with which users can manually adjust the reference voltage circuit errors. Note that a variable resistor may be affected by environmental conditions, resulting in resistance drift. For this reason it is recommended that this resistor should be calibrated after being used for a certain number of times, to ensure the accuracy of the reference voltage.

When considering the user requirements for the charger MCU resources, the calibration mode should minimise the use of resources. Therefore, a 1-wire communication interface is assigned, through which users can program the appropriate communication format according to their application requirements. During calibration, the charger communication pins (I/O and GND), the charger AC interface and the charger output interface should be correspondingly connected to the calibration fixture as shown below, to complete the calibration hardware configuration.



Calibration Fixture Application Circuit



Calibration Fixture Connection Diagram

Software Description

Users will have different requirements for their calibration protocols. The following provide a conceptual framework for users to design the protocol format according to their requirements. The accompanying software processes are described in terms of the fixture side and the charger side.

Fixture Side

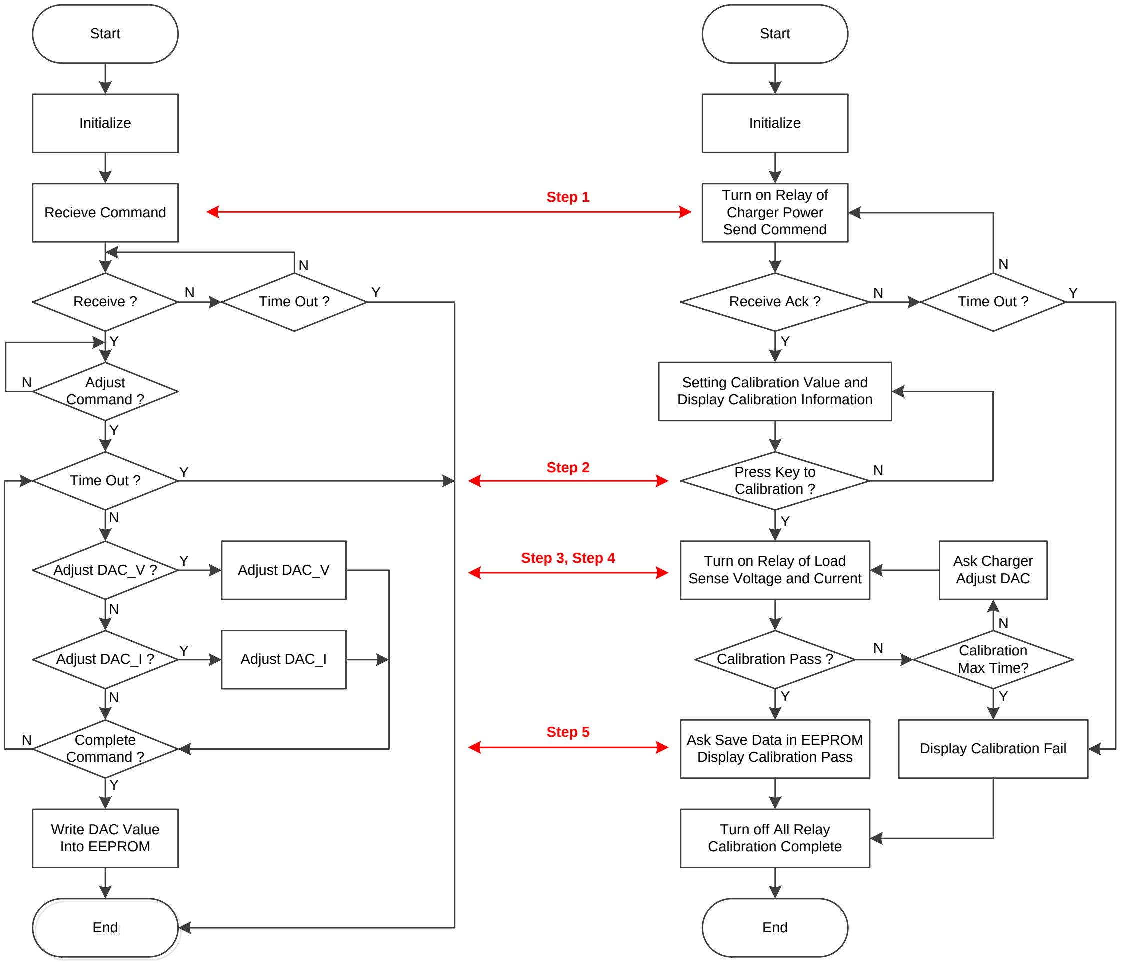
After power on, the fixture will wait until users press the calibration key to start communication. The fixture will turn on the charger power relay K1 during communication, send a communication command to require the charger to enter the calibration mode after a charger POR time of 50ms, and then wait for the charger to return an Ack signal. If the charger is unable to communicate with the charger for a time greater than 500ms, determine whether the communication has failed or if the charger is not connected, and then wait until the user presses the calibration key again to re-communicate.

After the communication is successful, the fixture will display the calibration information and begin to calibrate. The load relays, K2~K4, will be turned on sequentially to simulate battery loads using the cement resistors. Voltage or current measurement is implemented respectively by the resistor divider, R16 and R18, and the current sensing IC, U2. After each measurement, an increment or decrement command will be sent to require the charger to adjust the D/A converter to change the power output. If the calibration demand is met, command the charger to store the D/A converter parameters into the EEPROM and execute the next calibration stage. All relays, K1~K4, will be turned off and a calibration pass message will be displayed until all calibration stages have completed. For each calibration stage, the maximum number of calibration times is 20. If this number is exceeded, determine why the calibration has failed. This can avoid some errors caused by unusual conditions.

Charger Side

For 500ms after power on, the charger will check whether the fixture requires calibration or not. If a communication command is not received from the fixture in time, then enter the charger mode. If received, send an Ack signal, then complete the communication process and begin a calibration procedure.

At the beginning of calibration, the charger increases or decreases the internal D/A converter according to the fixture’s command to adjust the constant voltage and constant current values. The present D/A value will be written into the EEPROM until a calibration complete instruction has been received. The calibration procedure of this stage will now be complete. When the charger is powered on again and does not enter the calibration procedure, it will download the calibration value in the EEPROM to update the D/A converter and then start the normal charger procedure. For each calibration stage, the maximum number of calibration times is 20. If this number is exceeded, determine why the calibration has failed and cease any further adjustment. The calibration can restart only when a calibration command for the next stage has been received. This can avoid errors caused by unusual situations.



Charger Flowchart **Calibration Fixture Flowchart**

- Calibration Fixture Procedure Description

Step 1. Turn on the charger power control circuit after power on, determine whether the charger has entered the calibration mode or not.

- Step 2. Display the voltage and current calibration parameters and wait for the calibration key to be pressed.
- Step 3. Turn on the load and measure the charger output state, command the charger to adjust the D/A converter to fine tune the output voltage or current.

Step 4. When the charger output voltage or current meets with requirements, command the charger to store the calibration value into the EEPROM and display a calibration pass message. If the calibration has not completed in the maximum calibration time, command the charger to skip this calibration item and display a calibration fail message.

- Step 5. Repeat Step 3 and Step 4 until all voltage and current point calibrations have completed.

- Charger Procedure Description

  Step 1. Establish communication with the fixture after power on and then enter the calibration mode. However if this is not possible, rewrite the D/A converter with the EEPROM value, and enter the charging mode.

  Step 2. Wait for the fixture calibration key to be pressed and a start command to be sent, then begin the calibration procedure.

  Step 3. When a calibration command is sent by the fixture, adjust the D/A converter mode to fine tune the output voltage or current.

  Step 4. When a complete command is sent by the fixture, complete the calibration of this point. If it passes, store the D/A value into the EEPROM. If it fails, skip the calibration of this point. After this, execute the next calibration item.

  Step 5. Repeat Step 3 and Step 4 until the fixture has sent a calibration complete command before the calibration procedure has totally finished.

Connection Waiting Screen

Connection Confirmation Screen

Calibration Screen

Calibration Complete Screen

- The fixture presets four calibration points, trickle charging, constant current charging, constant voltage charging and float voltage charging, the details of which are described below:

  Trickle Charge (TC): This is implemented by a small constant current. When the battery is over discharging, a small current can be used to activate the battery.

  Constant Current Charge (CC): This is implemented by a large constant current, to prevent the battery from heating up rapidly which results in reduced battery life and charging efficiency.

  Constant Voltage Charge (CV): This is implemented by a constant voltage, to supplement the unfilled part after the constant current charge has completed.

  Float Voltage Charge (FV): This is implemented by a constant voltage to maintain battery self-discharge after the battery has been fully charged. This can also use the trickle charge mode.

- The fixture voltage and current AD values can be calculated using the following formulas:
  - Voltage AD value: $AD_{VBAT} = \frac{4096}{V_{REF}} \times \left(V_{BAT} \times \frac{R_{18}}{R_{16}+R_{18}}\right)$
  - Current AD value: $AD_{IBAT} = \frac{4096}{V_{REF}} \times (0.5 \times V_{CC} + 0.185 \times I_{BAT})$
  - For a current of 0.2A, the AD value is

$$AD_{IBAT} = \frac{4096}{4} \times (0.5 \times 5V + 0.185 \times 0.2A) = 2597 = A25H$$

  Note: In the Demo Board, R16=20kΩ, R18=1kΩ, VREF=4.0V, VCC=5.0V, IBAT= charging current

- The fixture calibration point information, the calibration register name and the setting values are summarised below:

Item	Register Name	Setting Value	
		Decimal	Hexadecimal
Trickle Charge (TC)=0.2A	C_MODE1_TARGET_H C_MODE1_TARGET_L	2597	0AH 25H
Constant Current Charge (CC)=2.0A	C_MODE2_TARGET_H C_MODE2_TARGET_L	2938	0BH 7AH
Constant Voltage Charge (CV)=59.2V	C_MODE3_TARGET_H C_MODE3_TARGET_L	2886	0BH 46H
Float Voltage Charge (FV)=55.0V	C_MODE4_TARGET_H C_MODE4_TARGET_L	2681	0AH 79H

Calibration Fixture Selection and Parameter Calculation

In the calibration fixture, the cement resistors is used to simulate battery loads, the resistor divider is used to measure the charger output voltage, and the current sensing IC is used to measure the charger output current. Special attention must be made to the resistance and the power in the cement resistor choice. For example, if the charger output voltage is 60V, and the output current is 2A, the resistance should be 30Ω $(R = \frac{V}{I})$, therefore the desired cement resistor must a have power rating of 120W $(P = I^2R)$. However, the actual load time of cement resistors in the calibration process must be taken into account, the power should be multiplied by a service time scale. Taking a service time scale of 1/5 as an example, the resistor power rating will reduce to about 24W.

The charger output voltage and current signals can be both measured by the MCU A/D converter in the fixture. The output voltage signal is read through the preset divider resistors, R16 and R18, with a resistance of 20kΩ and 1kΩ. This voltage signal value can be calculated using the following equation:

$$AD_{VBAT} = \frac{4096}{V_{REF}} \times \left(V_{BAT} \times \frac{R_{18}}{R_{16} + R_{18}}\right)$$

The output current signal is measured by the current sensing IC, where is the ACS712ELCTR-05B-T. More detailed specifications are shown below. This has a maximum supported measurement current of 5A, thus this current signal value can be calculated using the following equation:

$$AD_{IBAT} = \frac{4096}{V_{REF}} \times (0.5 \times V_{CC} + 0.185 \times I_{BAT})$$

The specifications are shown in the following red box

Taking the HT66F70A 12-bit A/D reference voltage of 4V as an example, the resolution can be calculated below:

$$I_{Resolution} = \frac{\frac{V_{REF}}{4096}}{0.185} \cong 5.3mA$$

In the fixture side, the voltage and the current can be accurately measured within a respective range of ±1% and ±5%. However, the calibration is still limited by the charger output power which corresponds to each level D/A converter. If the output power has exceeded this specification, the fixture cannot meet the calibration requirement even if measured accurately.

COMMON OPERATING CHARACTERISTICS[1] over full range of T_A, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
ELECTRICAL CHARACTERISTICS						
Supply Voltage	V_{CC}		4.5	5.0	5.5	V
Supply Current	I_{CC}	V_{CC} = 5.0 V, output open	–	10	13	mA
Output Capacitance Load	C_{LOAD}	VIOUT to GND	–	–	10	nF
Output Resistive Load	R_{LOAD}	VIOUT to GND	4.7	–	–	kΩ
Primary Conductor Resistance	$R_{PRIMARY}$	T_A = 25°C	–	1.2	–	mΩ
Rise Time	t_r	I_P = I_P(max), T_A = 25°C, C_{OUT} = open	–	3.5	–	μs
Frequency Bandwidth	f	–3 dB, T_A = 25°C; I_P is 10 A peak-to-peak	–	80	–	kHz
Nonlinearity	E_{LIN}	Over full range of I_P	–	1.5	–	%
Symmetry	E_{SYM}	Over full range of I_P	98	100	102	%
Zero Current Output Voltage	$V_{IOUT(Q)}$	Bidirectional; I_P = 0 A, T_A = 25°C	–	V_{CC} × 0.5	–	V
Power-On Time	t_{PO}	Output reaches 90% of steady-state level, T_J = 25°C, 20 A present on leadframe	–	35	–	μs
Magnetic Coupling[2]			–	12	–	G/A
Internal Filter Resistance[3]	$R_{F(INT)}$			1.7		kΩ

x05B PERFORMANCE CHARACTERISTICS[1] T_A = –40°C to 85°C, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–5	–	5	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	180	185	190	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	21	–	mV
Zero Current Output Slope	$\Delta V_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.26	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.054	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.008	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P = ±5 A, T_A = 25°C	–	±1.5	–	%

Current sensing IC ACS712ELCTR-05B-T Specification Table

Advantages and Disadvantages of Automatic and Traditional Fixtures

	Automatic Fixtures	Traditional Fixtures
Calibration Mode	One-click - time saving	Manual - time consuming
Labour Requirement	One person	Several people
Calibration Accuracy	Accurate calibration provided by internal D/A	Limited by external components
Calibration Time	10 second/platform↓	1 minute/platform↑

Conclusion

This application note has introduced the hardware, software, calibration register names and parameter calculation formulas, as well as the program flowchart and procedure, to allow users to understand the charger calibration process, principles, methods and considerations. This can assist users to rapidly and flexibly design their own calibration fixture or use Holtek's calibration fixture, thereby eliminating the need for traditional manual calibration, and greatly improving production efficiency.

Versions and Modification Information

Date	Author	Issue Release and Modification
2017.10.31	李昱緯	First Version

References

Reference document: HT66F70A Data Sheet.

For more information, refer to the Holtek's official website: http://www.holtek.com/en/.

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