AN13233

Using MC33775A with fewer than 14 cells or in busbar application

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Application note
CONFIDENTIAL

Document information

Information	Content
Keywords	MC33775A, fewer than 14 cells, busbar, 12 cell application, 8 cell application
Abstract	The MC33775A is a 14 cell battery controller IC. The MC33775A can also be used in applications that use fewer than 14 cells. Another feature of the MC33775A is to be able to monitor busbars. When not all 14 cell inputs are used, or busbars are measured, connection options are possible. The document summarizes the constraints that must be followed for such applications. The document shows the recommended connection options for a few selected configurations.

Revision history

Rev	Date	Description
1	20220930	initial version

1 Introduction

The MC33775A is a lithium-ion battery cell controller IC designed for automotive applications, such as hybrid electric vehicle (HEV) and electric vehicle (EV). It can be used in industrial applications, such as energy storage system (ESS) and uninterruptible power supply (UPS) systems. The device measures differential high precision cell voltages as well as temperatures. Additionally, the device provides an extensive set of passive cell voltage balancing features to equalize the individual cell voltages across the battery stack. The device offers serial peripheral interface (SPI) and an isolated daisy chain interface for communication with the host MCU. The MC33775A offers increased safety level and a low bill of materials.

1.1 Numbering scheme

Inside this document, the numbering scheme for the cells is kept the same all the time. The lowest cell, connected between CT0 and CT1 is called cell 0. Cell 1 is connected between CT1 and CT2, cell 2 between CT2 and CT3 and so on. The highest cell is cell 13, connected between CT13 and CT14. If a cell input is not used, or replaced with a busbar, the cell numbering for the other cells is not modified. This scheme allows an easier identification of the differences between the various circuits.

2 Basic circuits

Due to the electrical constraints of the MC33775A, it is not recommended to skip the first cell. Also for the last cells are some constraints. Consequently inputs in the middle must be skipped. The balancing inputs of the MC33775A do not allow for negative voltages. If a busbar is present, the balancing inputs for this channel must be skipped.

2.1 Basic circuits when skipping an input

When an input between cell 0 to cell 7 is not used, the not used cell terminal pins (CTx) must be connected to the next lower cell. When an input between cell 8 to cell 13 is not used, the not used cell terminal pins (CTx) must be connected to the next higher cell. Not used cell balancing pins (CBx) must be connected to the corresponding CBxC pin.

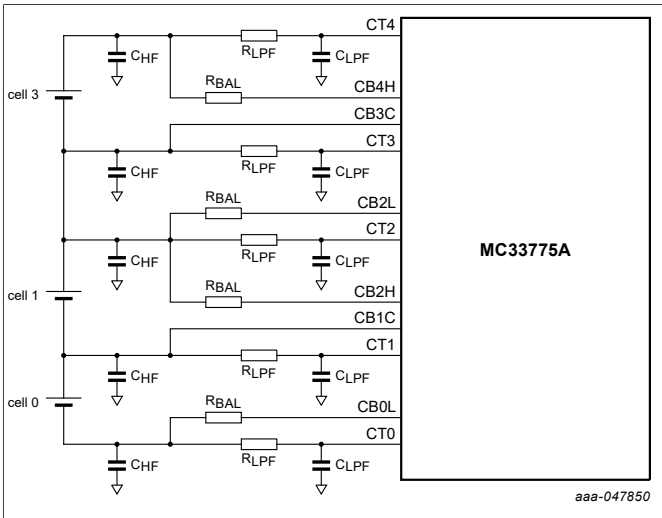


Figure 1. Full population

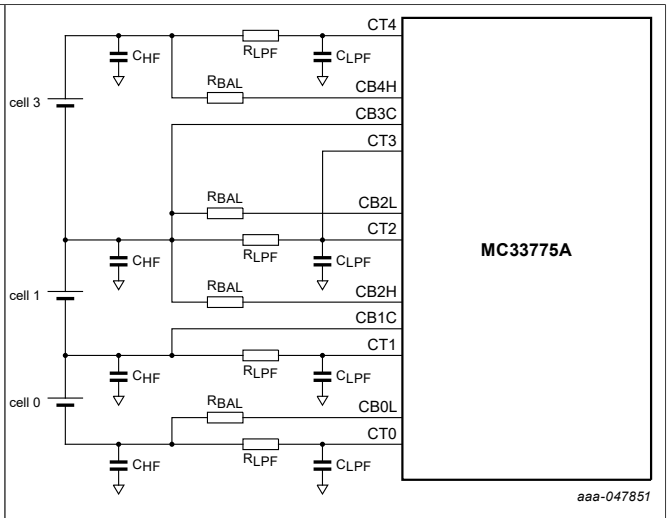


Figure 2. Reduced population

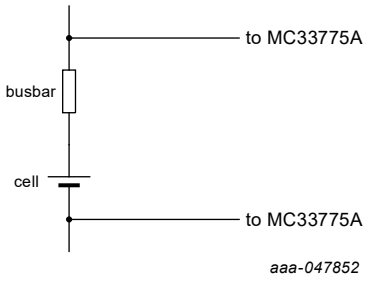
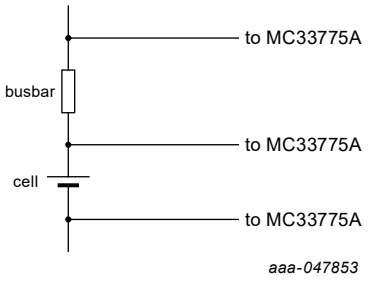
Figure 1 shows a connection option for skipping cell 2 while keeping all components populated. The not connected input has no influence on the other inputs. Since no components are removed, there is no BOM cost saving compared to a fully utilized application.

A different option is shown in Figure 2. Here the input filter connected to CT3 and one of the C_{HF} capacitors is removed. As leakage currents from CT2 and CT3 are now accumulating, there is a small influence on accuracy of the measurement. If the recommendations in the data sheet are followed, and only one cell is skipped at a time, the impact on accuracy is limited. If two or more cells are skipped, it is recommended to skip only the low-pass filters (LPFs) that are not used by any measurement. Section 5.2 shows an example for such a configuration.

2.2 Basic circuits for busbar connection

For a busbar connection, there are two basic configurations possible. Table 1 summarizes the connection options and their advantages.

Table 1. Connection options for busbars

Configuration	Busbar in series with a cell	Separate input for busbar
Drawing	 **Figure 3. Busbar in series with a cell**	 **Figure 4. Separate input for busbar**
Advantage	The busbar does not occupy a channel.	busbar and cell are measured independently of each other
Disadvantage	measurement is for busbar plus cell; no separate measurement for each quantity	The busbar occupies one channel.

Assuming, the combined voltage drop across the busbar and the cell voltage stays between 0 V and the saturation value of the MC33775A, the option busbar in series with a cell behaves for the MC33775A like a regular cell. No specific constraints arise. The default circuit for a cell is applicable.

When the busbar is connected separately to the MC33775A, it is possible that the voltage across the busbar is negative. The cell terminal inputs (CTx pins) of the MC33775A can handle negative voltages of up to −5 V. The cell balancing inputs (CBx pins) however can handle only −0.3 V. Consequently the CBx pins must not be connected to the busbar. The not used CBx_H or CBx_L pin must be connected to the corresponding CBx_C pin instead. To avoid risks during hot plug, it is recommended to keep the balancing resistor (R_{BAL}) in place. However, since the balancing resistor does not dissipate power, it is possible to reduce the form factor of the balancing resistor.

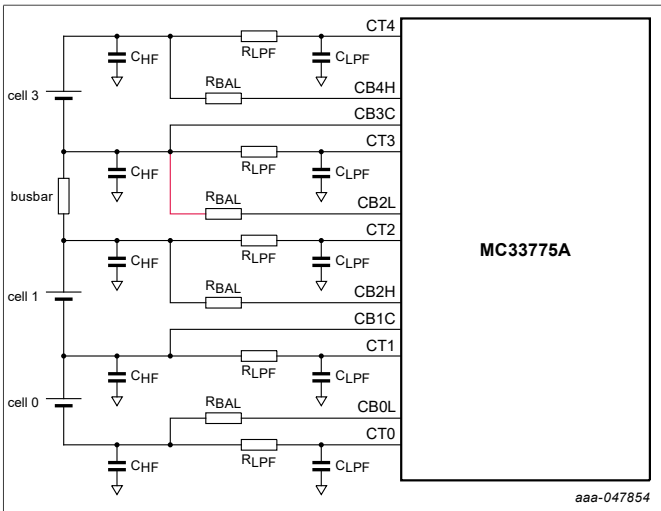


Figure 5. Busbar at CBx_L

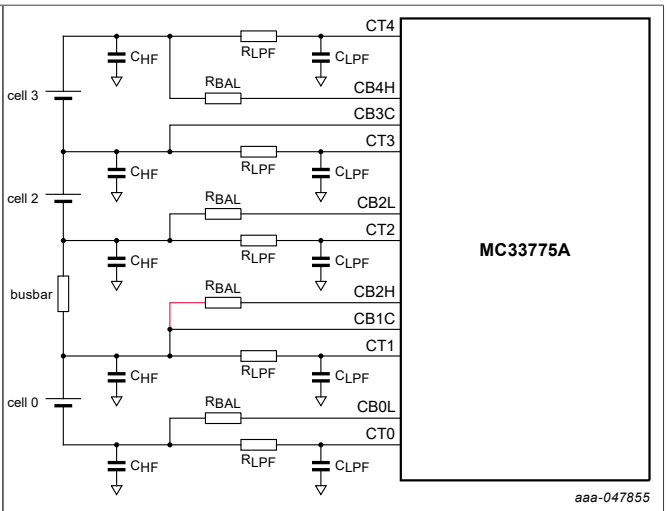


Figure 6. Busbar at CBx_H

In Figure 5, cell 2 is replaced by a busbar. Cell 2 is normally balanced via the CB2L and CB3C pins. To avoid negative voltage across the pins, CB2L is now connected to CB3C.

In Figure 6, cell 1 is replaced by a busbar. Cell 1 is normally balanced via the CB1C and CB2H pins. To avoid negative voltage across the pins, CB2H is now connected to CB1C.

Note: *As the busbar is not connected to the balancing inputs, there is no redundant measurement for the busbar available.*

3 Hardware constraints

When defining the correct external circuit for the cell terminal input voltages, some constraints must be considered:

- **Leakage currents in the IC**: The way the internal circuit of the IC is designed results in some leakage currents at the cell terminal inputs. Together with the anti-aliasing filter, this leakage current may cause an error in the voltage measurement. If only one cell is skipped, and the recommendations in the data sheet are followed, it is possible to skip the input filter for the not connected cell. If more cells are skipped, it is recommended to keep the input filter before, and after the not used inputs (see Section 5.2).
- **System cost**: Some connection option use more, other fewer components. The number of components has an impact to the system cost. The full population option shown in Figure 1 has higher BOM costs than the option with reduced population (Figure 2). However, reusability of the full population option may be higher.
- **Hot plugging**: When the system is connected to the battery for the first time, all capacitors on the printed-circuit board (PCB) must be charged. As the connection can happen in any order, there can be some stress to the pins of the IC. Certain connection options may cause more or less stress for the IC pins. For this reason, it is recommended to keep the balancing resistors in place even when not needed for normal operation. Since there is no power dissipation inside the balancing resistors, a smaller form factor can be used.
- **Voltage constraints**: The data sheet of the MC33775A lists some voltage constraints for the IC. Whatever configuration is applied to the IC, the constraints listed in the data sheet must be met.

4 Software considerations

If a cell input is not used, or a busbar is present there are some consequences for the software (SW).

4.1 Enabling of the voltage measurements

The configuration of the voltage measurement enable should always be done via the ALLM_VCVB_CFG register. The ALLM_VCVB_CFG register ensures that the settings for the primary and the secondary measurement are equal. An unequal setting of the PRMM_VC_CFG register and the SECM_VB_CFG results in different timings for the primary and the secondary measurement. Any timing difference between the primary and secondary measurement triggers a synchronous measurement fault (SYNCMEASFLT). A SYNCMEASFLT is reported in the FEH_MEAS_FLT_STAT register and leads to an invalidation of the secondary measurement results.

Note: *For busbars, only the primary measurement is used. Still primary and secondary measurements must be enabled.*

Note: *Disabling an input has no influence on the measurement timings of the primary measurement. The secondary measurement skips not enabled inputs. FastVB or SYNC measurements cycles are completed faster.*

Note: *For busbars, the secondary measurement is not available. Comparison of primary and secondary measurement is not useful for busbars.*

Note: *Disabled inputs return invalid (8000h) as measurement result and do not take part of undervoltage and overvoltage comparisons.*

4.2 Cell voltage overvoltage and undervoltage checks

The MC33775A runs comparisons of the cell voltages against configurable voltage thresholds. The measurement of a busbar would typically be very low which triggers an undervoltage event. The register PRMM_VC_OV_UV_CFG allows enabling and disabling the undervoltage and overvoltage checks. To avoid triggering of unintended events, only inputs where cells are connected should be enabled.

4.3 Cell connection test

The voltage drop across a busbar is typically very low. If there is no current flowing, the voltage drop is 0 V. The cell connection test as described in AN12915 is using the ratio between two voltage measurement to determine if the connection is good or interrupted. With low amplitudes for the measurement, the ratio calculation is very sensitive to inaccuracies and noise. Consequently the ratio-based diagnostic is not suitable for busbar connections. However, a busbar shares typically the connection with a cell. A fault in the connection of the busbar, is also a fault in the connection of the cell. Therefore the cell connectivity test flags the fail of the busbar connection.

The cell and busbar configuration chosen (full population or reduced population; position and connection option of the busbar), is influencing the dynamic behavior of the system and may require an adaptation of the detection thresholds.

4.4 Balancing fault monitoring

When the balancing is enabled, the MC33775A is monitoring the status of the balancing switches by measuring the voltage drop across the balancing switch. If the balancing switch is not connected to a cell, the voltage drop across the switch is 0 V. The MC33775A considers such low voltage as a mismatch of the intended switch state and signals a balancing fault (BALFLT). The BALFLT is signaled in the FEH_ANA_FLT_EVT_CFG register and propagated to an analog fault (ANAFLT). The BAL_SWITCH_MON_CFG allows disabling the monitoring for individual balancing switches and therefore avoids generating a BALFLT.

5 Examples

This section lists recommended configurations for commonly used configurations.

5.1 Example 1: 12 cell application

The first example is a 12 cell application connected as per the recommendations from the data sheet.

5.1.1 Hardware configuration

Figure 7 shows and example circuit for an application with 12 cells where cell 4 and cell 9 are skipped.

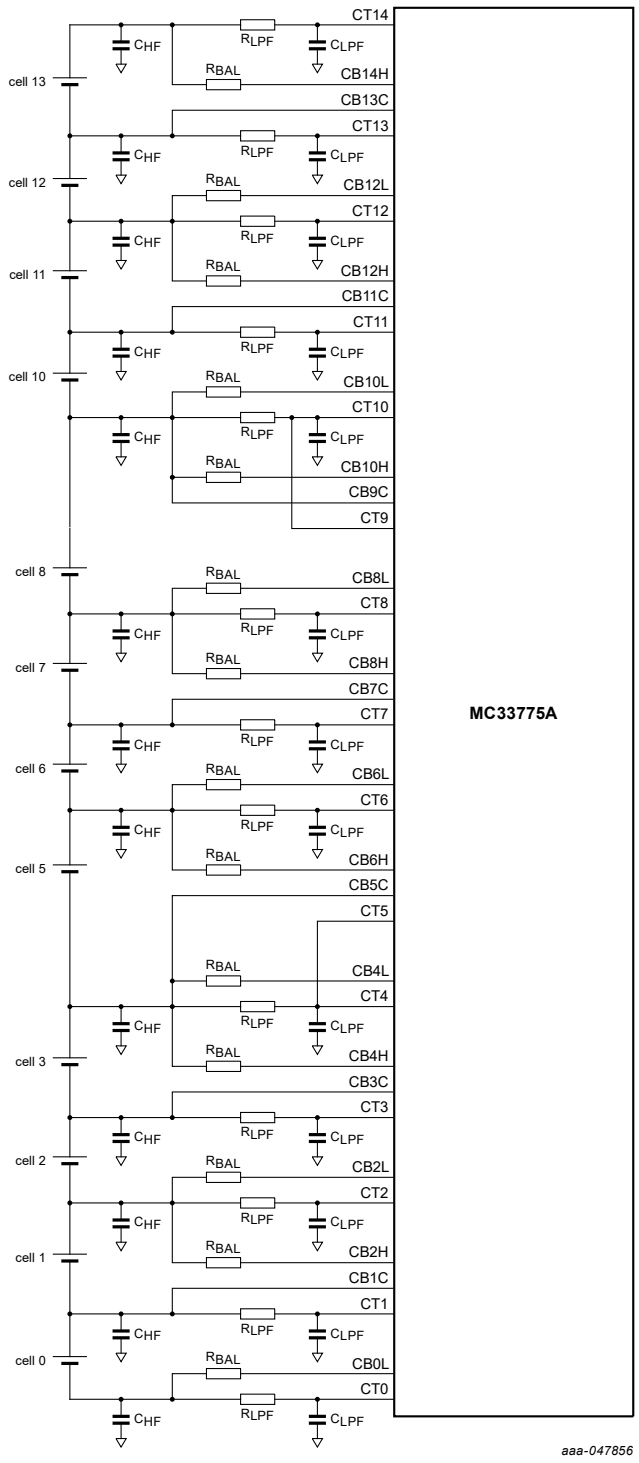


Figure 7. Example for 12 cell application

5.1.2 Software configuration

Table 2 shows the relevant registers which are mentioned in Section 4 and that are deviating from the reset configuration of the MC33775A.

Table 2. Register settings for example 1

Register	Recommended setting	Comment
PRMM_VC_CFG and SECM_VB_CFG	0011 1101 1110 1111b = 3DEFh	Enable the measurement only for used inputs. Use ALLM_VC_CFG to configure PRMM_VC_CFG and SECM_VB_CFG simultaneously.
PRMM_VC_OV_UV_CFG	0011 1101 1110 1111b = 3DEFh	Not mandatory since used cells return invalid and do not take part of the comparison.
BAL_SWITCH_MON_CFG	0011 1101 1110 1111b = 3DEFh	Avoid triggering of balancing faults for not connected cells.

5.2 Example 2: 8 cell application

The second example is an 8 cell application connected as per the recommendations from the data sheet.

5.2.1 Hardware configuration

Figure 8 shows an 8 cell application. This configuration switches two times three cells. To avoid the impact of the leakage currents, the additional filter is placed.

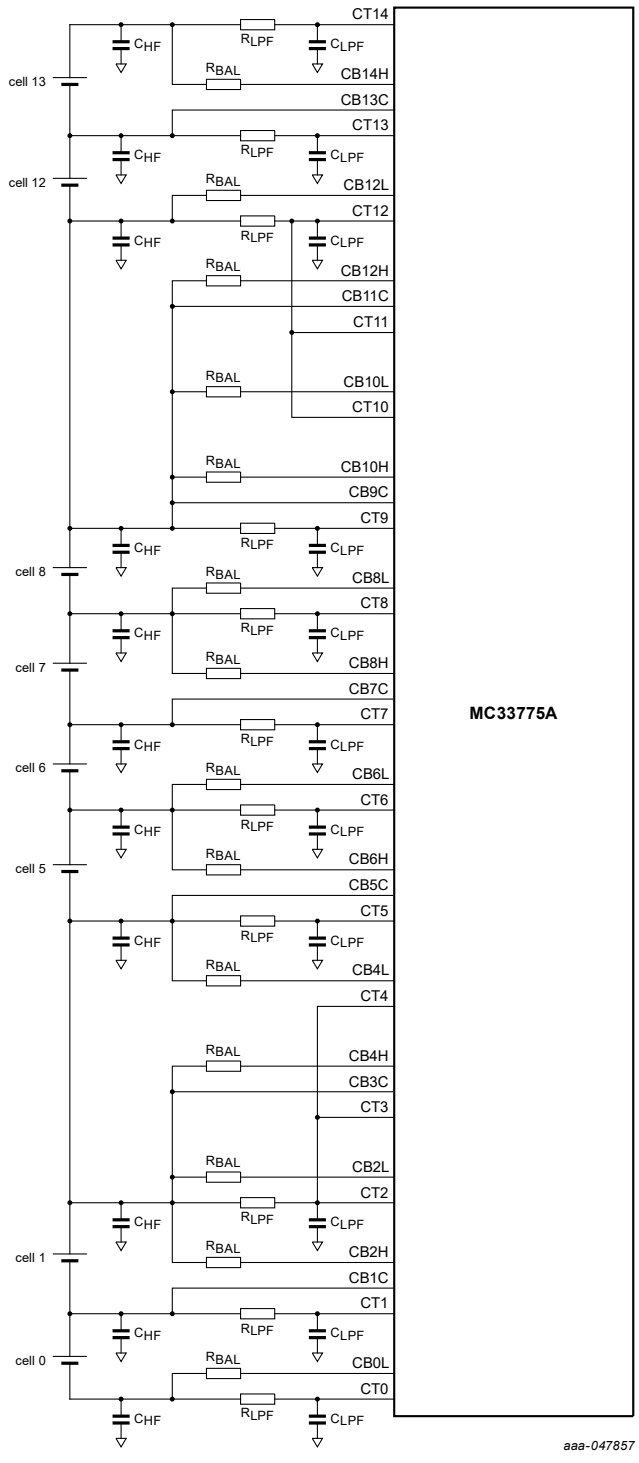


Figure 8. Example for 8 cell application

5.2.2 Software configuration

Table 3 shows the relevant registers which are mentioned in Section 4 and that are deviating from the reset configuration of the MC33775A.

Table 3. Register settings for example 2

Register	Recommended setting	Comment
PRMM_VC_CFG and SECM_VB_CFG	0011 0001 1110 0011b = 31E3h	Enable the measurement only for used inputs. Use ALLM_VC_CFG to configure PRMM_VC_CFG and SECM_VB_CFG simultaneously.
PRMM_VC_OV_UV_CFG	0011 0001 1110 0011b = 31E3h	Not mandatory since used cells return invalid and do not take part of the comparison.
BAL_SWITCH_MON_CFG	0011 0001 1110 0011b = 31E3h	Avoid triggering of balancing faults for not connected cells.

5.3 Example 3: 12 cell module with 3 times 4 cells and 2 busbars

The third example is a 12 cell application with 2 busbars monitoring 3 blocks for 4 cells each.

5.3.1 Hardware configuration

Figure 9 shows and example circuit for an application with 12 cells. Three blocks, each with four cells, are monitored. In-between the blocks are busbars that are monitored as well.

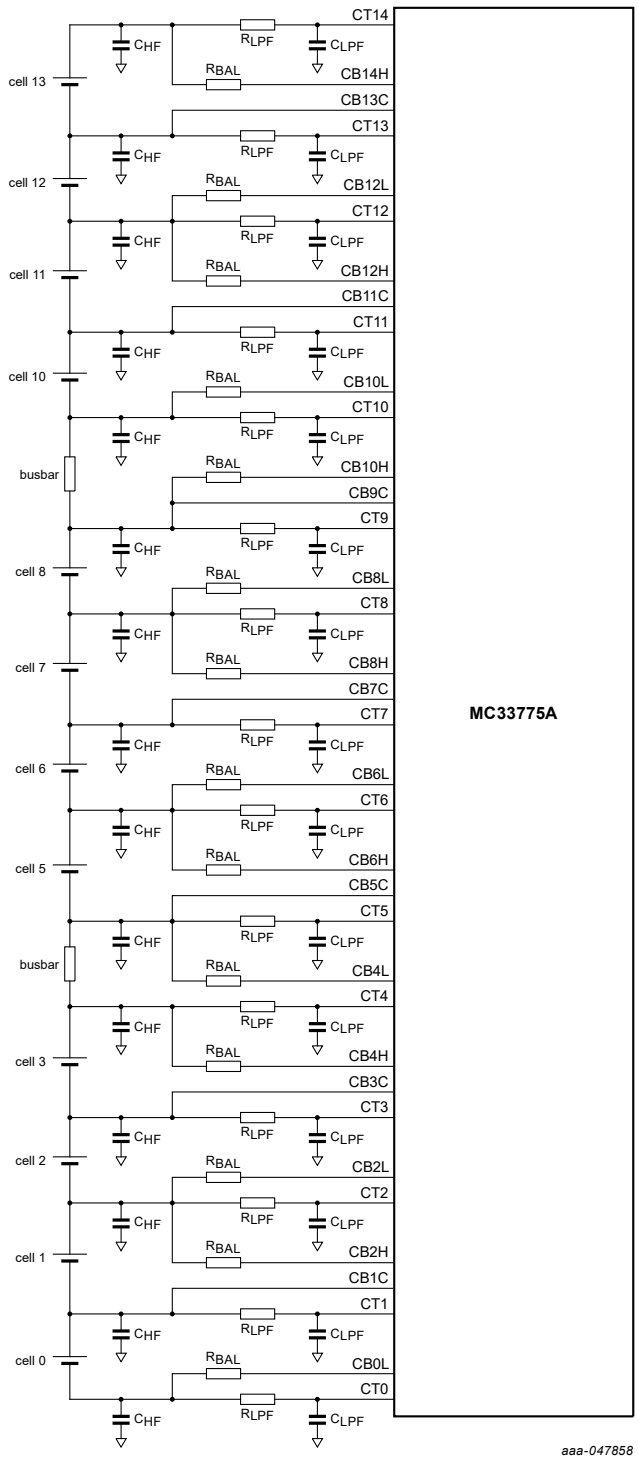


Figure 9. Example for 12 cell application with 3 × 4 cells

5.3.2 Software configuration

Table 4 shows the relevant registers which are mentioned in Section 4 and that are deviating from the reset configuration of the MC33775A.

Table 4. Register settings for example 3

Register	Recommended setting	Comment
PRMM_VC_CFG and SECM_VB_CFG	0011 1111 1111 1111b = 3FFFh	All 14 inputs are used for measurements. Use ALLM_VC_CFG to configure PRMM_VC_CFG and SECM_VB_CFG simultaneously.
PRMM_VC_OV_UV_CFG	0011 1101 1110 1111b = 3DEFh	Exclude busbars from undervoltage and overvoltage comparison.
BAL_SWITCH_MON_CFG	0011 1101 1110 1111b = 3DEFh	Avoid triggering of balancing faults for busbars.

5.4 Example 4: 12 cell module with 2 times 6 cells and 2 busbars

The fourth example is a 12 cell application with 2 busbars monitoring two blocks of six cells each.

5.4.1 Hardware configuration

Figure 10 shows and example circuit for an application with 12 cells. Two blocks, each with six cells, are monitored. The position of cell 6 is measuring the busbar between the blocks. The position for cell 13 is monitoring the busbar to the next module. In this configuration, special care must be taken on the constraint of V_{BAT} + 2.2 V − $\Delta V_{max1(VBAT-CT14)}$ listed in the data sheet. If high negative voltage drops or large deviations between the voltage at the VBAT and the CT14 pin are expected, this configuration may violate the constraints for the MC33775A.

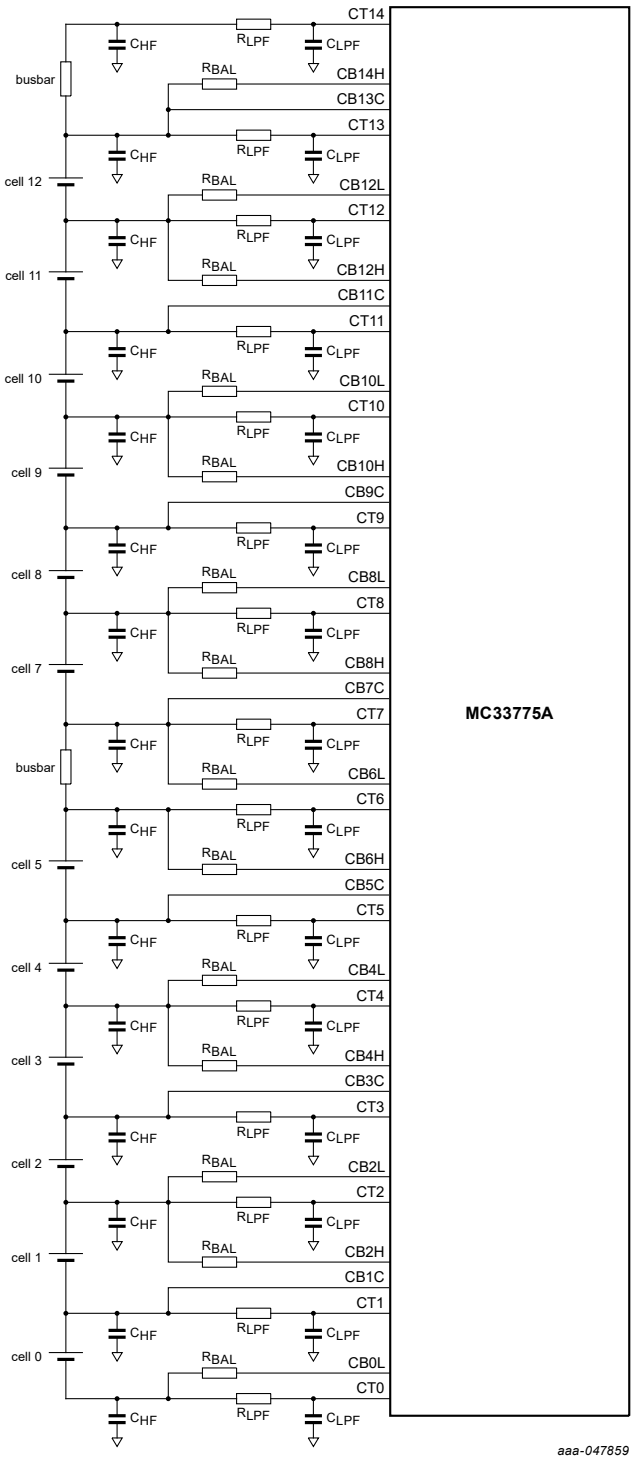


Figure 10. Example for 12 cell application with 2 × 6 cells

5.4.2 Software configuration

Table 5 shows the relevant registers which are mentioned in Section 4 and that are deviating from the reset configuration of the MC33775A.

Table 5. Register settings for example 4

Register	Recommended setting	Comment
PRMM_VC_CFG and SECM_VB_CFG	0011 1111 1111 1111b = 3FFFh	All 14 inputs are used for measurements. Use ALLM_VC_CFG to configure PRMM_VC_CFG and SECM_VB_CFG simultaneously.
PRMM_VC_OV_UV_CFG	0001 1111 1011 1111b = 1FBFh	Exclude busbars from undervoltage and overvoltage comparison.
BAL_SWITCH_MON_CFG	0001 1111 1011 1111b = 1FBFh	Avoid triggering of balancing faults for busbars.

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