

M61040FP

Smart Battery Protection and Monitoring IC

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Description

The M61040FP is intended to be used as SB: Smart Battery.

All functions needed for SB are packed to this M61040FP. The combination use with microcomputer such as M37515 will give various functions such as a detection or calculation of SB remaining capacity. Over current detection circuit dedicated in M61040FP will give safety FET on/off control independent from microcomputer control.

The amp gain of charge/discharge current detection circuit is controlled by microcomputer, therefore the accuracy of SB's remaining capacity detection becomes better than before. The reset circuit and the linear regulator for V_{CC}/V_{ref} of microcomputer are dedicated in M61040FP. So this will help easy design of power circuit design of SB.

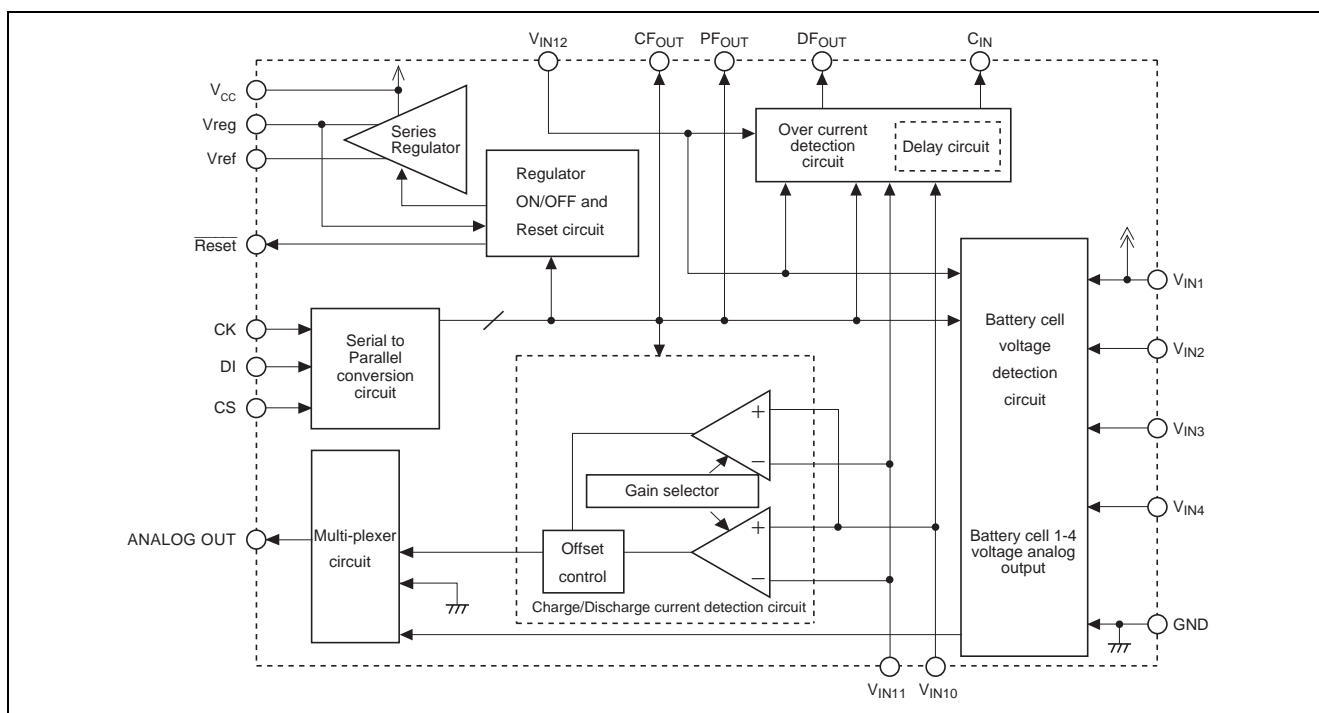
Features

- Built-in high gain op-amps for monitoring charge/discharge current
- Built-in over current detection circuit for FET protection
- All FETs are controlled by microcomputer
- Various powers saving function to reduce total power dissipation
- High input voltage device (absolute maximum rating: 33 V)

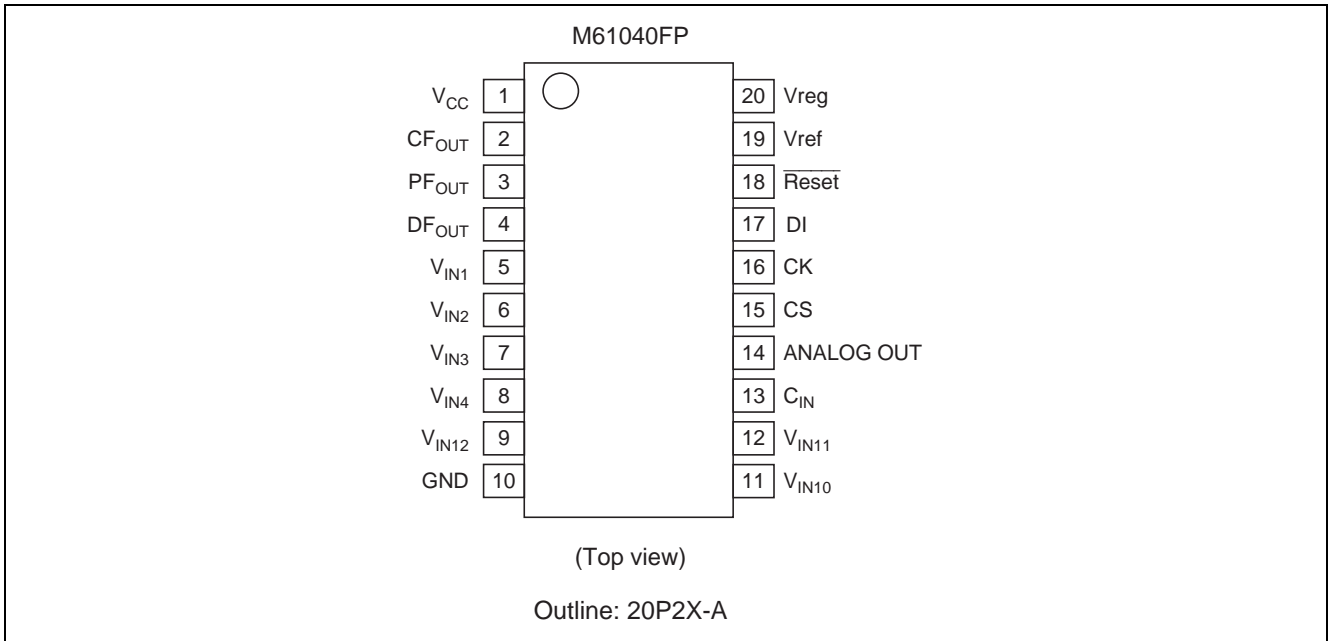
Application

Smart battery system

Block Diagram



Pin Arrangement



Pin Description

Pin No.	Pin Name	Functions
5	V _{IN1}	Battery 1 + voltage input
6	V _{IN2}	Battery 1 – voltage and battery 2 + voltage input
7	V _{IN3}	Battery 2 – voltage and battery 3 + voltage input
8	V _{IN4}	Battery 3 – voltage and battery 4 + voltage input
9	V _{IN12}	Monitoring charger is connected or not
13	C _{IN}	Connect capacitor for over current detection delay
11	V _{IN10}	Charge/discharge current monitor input and connects charge/discharge current sense resistor
12	V _{IN11}	Charge/discharge current monitor input and connects charge/discharge current sense resistor
1	V _{CC}	Power source pin. Power from charger or battery
10	GND	Ground
20	V _{reg}	Linear-regulator output for microcomputer
19	V _{ref}	V _{reg} voltage output for V _{reg} of microcomputer, Max 200 μA/5 V
18	$\overline{\text{RESET}}$	Reset signal output to RESET of microcomputer
14	ANALOG OUT	Various analog signal outputs to AD-input of microcomputer
4	DF _{OUT}	Discharge FET-drive output. The driver is turned off when over current detected.
2	CF _{OUT}	Charge FET-drive output. The driver is turned off by microcomputer.
17	DI	Input of 6-bit length serial data from microcomputer
16	CK	Input of shift clock from microcomputer. DI's input data is latched by low-to-high edge of this CK
15	CS	During low signal input to this CS, data input to DI is enabled.
3	PF _{OUT}	Pre-charge FET-drive output. The driver is turned off by microcomputer.

Absolute Maximum Ratings

Item	Symbol	Ratings	Unit
Absolute maximum rating	Vabs	33	V
Supply voltage	V _{CC}	30	V
Power dissipation	Pd	750	mW
Operating temperature range	Topr1	-20 to +85	°C
Storage temperature range	Tstg	-40 to +125	°C

Electrical Characteristics

(Ta = 25°C, V_{CC} = 14 V, unless otherwise noted)

	Item	Symbol	Min	Typ	Max	Unit	Circuit	Test Conditions
Total	Supply voltage	V _{CC}	—	—	30	V		
	Supply current 1	I _{sup1}	105	200	280	μA	7	Voltage monitor, V/R, reset ON, current monitor ON
	Supply current 2	I _{sup2}	65	120	165	μA	7	Voltage monitor, V/R, reset ON, current monitor OFF
	Supply current (at power save mode)	I _{ps}	35	60	85	μA	7	Regulator ON, non-loading, reset circuit ON, others OFF
	Supply current (at power down mode)	I _{pd}	—	—	0.5	μA	7	All operation stop, V _{IN12} = GND
Regulator	Output voltage	V _{reg}	5.145	5.2	5.295	V	3	I _{out} = 20 mA
	Input and output voltage difference	V _{dif0}	—	0.3	0.8	V	3	I _{out} = 20 mA
	Linear regulation	ΔV _{out10}	—	100	200	mV	3	V _{CC} = 6.2 to 24 V, I _{out} = 20 mA
	Load regulation	ΔV _{out20}	—	30	45	mV	3	V _{CC} = 6.2 V, I _{out} = 50 μA to 20 mA
	Input voltage	V _{IN0}	—	—	30	V		V _{CC} voltage
Reference voltage	Output voltage	V _{ref}	4.818	4.85	4.917	V	4	I _{out} = 200 μA
	Load stability	ΔV _{out21}	—	5	45	mV	4	V _{CC} = 6.2 V, I _{out} = 50 to 200 μA
Over current detection	Over current inhibit detection voltage 1	V _{cl}	V _{CL} - 0.02	0.2	V _{CL} + 0.02	V	8	
	Over current inhibit detection voltage 2	V _{ch}	$\frac{V_{CC}}{3} \times 0.6$	$\frac{V_{CC}}{3}$	$\frac{V_{CC}}{3} \times 1.4$	V	8	Load short detection
	Over current inhibit detection delay time 1	T _{vcl}	7	10	15	ms	5	CICT = 0.01 μF
	Over current inhibit detection delay time 2	T _{vch}	150	250	350	μs	8	
Battery voltage detection	Input offset voltage	V _{off1}	31	208	385	mV	5	
	Voltage gain 1	G _{amp1}	0.99	1.0	1.01	—	5	
	Output source current	I _{source1}	150	—	—	μA	10	
	Output sink current	I _{sink1}	150	—	—	μA	10	
	Detection voltage of battery cell	V _{ref-Voff1}	4.45	—	—	V	5, 6	

	Item	Symbol	Min	Typ	Max	Unit	Circuit	Test Conditions
Charge/ discharge current detection	Input offset voltage	Voff2	0.2	2	3.8	V	5	Gain = 200 selected
	Voltage gain 21	Gain21	38.4	40	41.6	V	5	
	Voltage gain 22	Gain22	96	100	104	V	5	
	Voltage gain 23	Gain23	192	200	208	V	5	
	Output source current	Isouce2	150	—	—	μA	9	
	Output sink current	Isink2	150	—	—	μA	9	
Interface	DI input H voltage	VDIH	3.5	—	Vreg	V	1	
	DI input L voltage	VDIL	0	—	0.5	V	1	
	CS input H voltage	VCSH	3.5	—	Vreg	V	1	
	CS input L voltage	VCSL	0	—	0.5	V	1	
	CK input H voltage	VCKH	3.5	—	Vreg	V	1	
	CK input L voltage	VCKL	0	—	0.5	V	1	
Reset	Detection voltage1	Vdet-	3.045	3.25	3.475	V	2	
	Release voltage1	Vdet+	4.16	4.2	4.27	V	2	
Conditioning circuit	V _{IN1} resistor	R _{INV1}	4.4	12	27	kΩ	6	
	V _{IN2} resistor	R _{INV2}	4.4	12	27	kΩ	6	
	V _{IN3} resistor	R _{INV3}	4.4	12	27	kΩ	6	
	V _{IN4} resistor	R _{INV4}	4.4	12	27	kΩ	6	

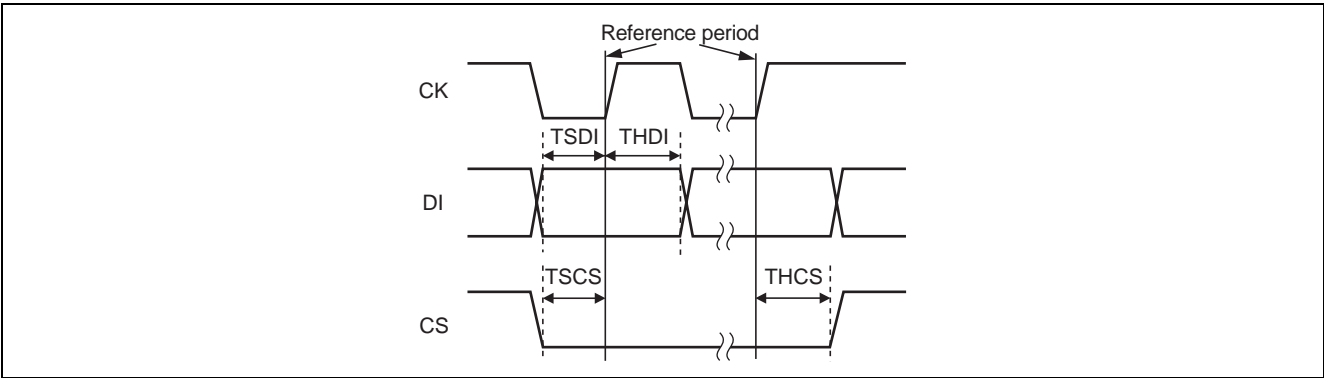


Figure 1 Interface Timing

Operation Description

M61040 is developed for intelligent Li-ion battery pack such as SB in SBS. M61040 is suitable for smart battery.

- SBS: Smart Battery System introduced by Intel and Duracell
- SB: Smart Battery which contains 3 or 4 series Li-ion battery cells.

All analog circuits are included to M61040. Therefore pair using with microcomputer such as M37515 and small additional parts will give various functions such as battery remaining capacity detection. All functions are described as follows:

1. Voltage detection circuit of each Li-ion battery cells
M61040 can output each battery cell's voltage of 3 or 4 series connection. Built-in buffer amplifier is monitoring each battery voltage. Microcomputer can adjust the offset voltage.
2. Charge/discharge current detection circuit
In SBS, remaining capacity check function (Gas-gage function) is necessary. To calculate accurate remaining capacity, microcomputer must get charge/discharge current periodically. Accurate charge/discharge current of external sense register is monitored by built-in amp. The charge/discharge current is converted to voltage value through the accurate sense resistor.
Output gain can be controlled by microcomputer. Off-set voltage can be set lower by external parts, therefore dynamic range of microcomputer's A to D converter will widen.
3. Over current detection circuit
M61040 contains over current detection circuit. The discharging FET is turned off to stop discharging and it continues for the over current detection delay time (t_{IOV1}) or longer, if the discharging current becomes equal to or higher than a specified value. It is necessary for safety of Li-ion battery pack. Delay time is set by external capacity connected to CIN. Also the voltage of CIN shows detection or NOT detection of over current. Over current detection is controlled independently by this M61040's built-in hardware NOT by microcomputer's software control.
4. Series regulator, reference voltage
M61040 contains low drop out series regulator. Microcomputer in SB does not need any additional voltage regulator, Max 20 mA/5 V. Also M61040 gives very accurate reference voltage as 4.85 V for Vref voltage for microcomputer's A to D converter.
5. Reset circuit for microcomputer
Vreg output voltage is checked by reset circuit of M61040. Therefore, lower voltage of Vreg issues RESET signal to stop mull-function of microcomputer. Also, lower voltage after long time's left issues RESET signal to stop mull-function of microcomputer. This function is useful for safety of long time's left battery.
When charger is connected to SB, this circuit will check Vreg voltage, so if Vreg voltage is NOT enough high, this circuit remains low as for RESET signal to microcomputer.
6. Power save function
M61040FP contains power save function to control several supply current.
The function and control method are shown as table 1.
The function of battery voltage detection circuit, charge/discharge detection circuit, over current detection circuit can be stopped as the need arises.

Table 1

Control Method	Battery Voltage Detection Circuit	Charge/Discharge Detection Circuit	Over Current Detection Circuit
Software control (through serial I/F)	○	○	○
Each function can be ON/OFF separately.			

— Enter power down mode

Microcomputer issues shot-down command to M61040 after microcomputer detects that battery voltage is too low. After this command, the DFOUT pin is set to "high" and the V_{IN12} pin is pulled down by internal resistor to be set "low" and series regulator are turned off.

In the power down mode, the M61040 operation is impossible. And CFOUT, DFOUT and PFOUT pins are set to "high". (In this situation, both charging and discharging are forbidden.)

At this time, supply current becomes Max 1.0 μ A, so drops of battery voltage is prevented.

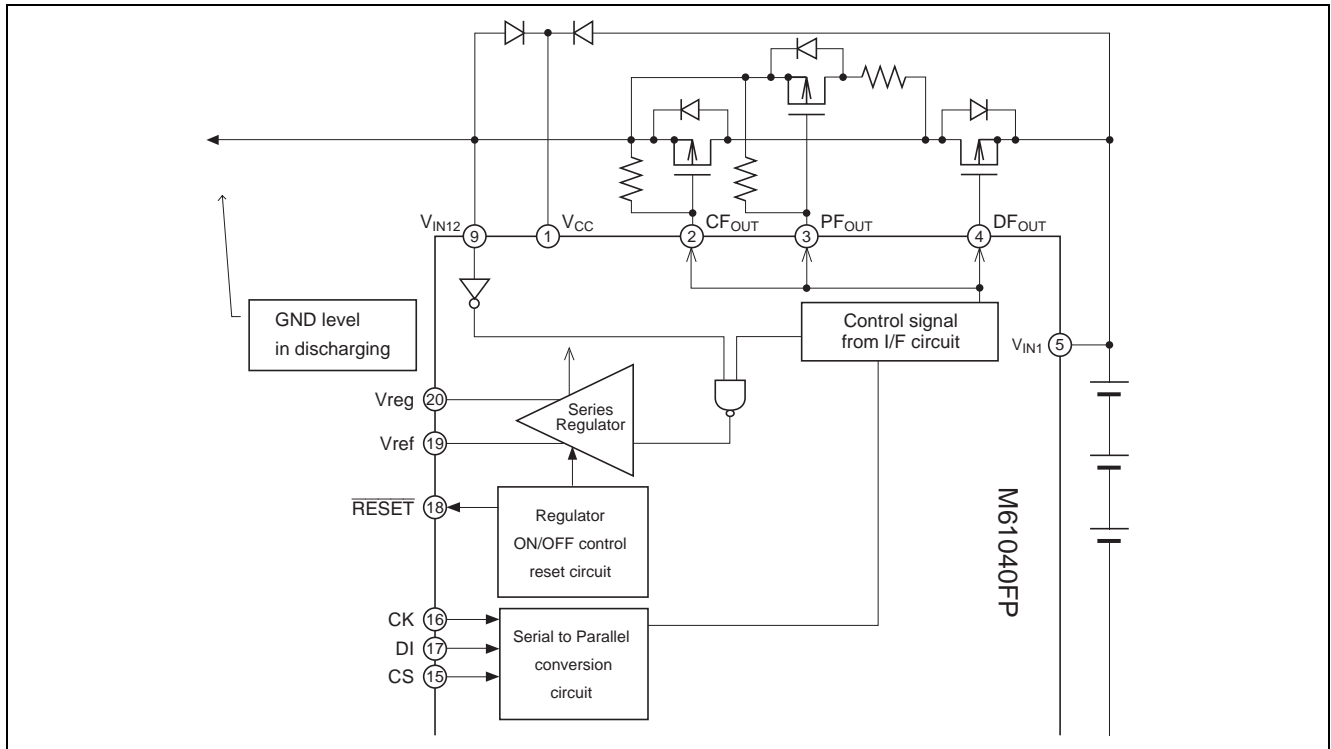


Figure 2 Function after Detecting Over-discharge

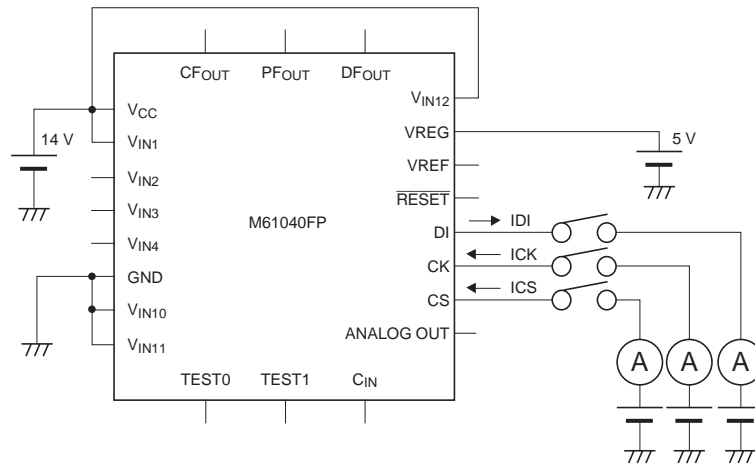
— Resume from power down mode

After entering power down mode, the series regulator will begin operation when charger is connected (V_{IN12} pin is high). The RESET will output low to high signal when Vreg is over reset level voltage. Microcomputer will begin operation and send command to resume M61040 from power down mode.

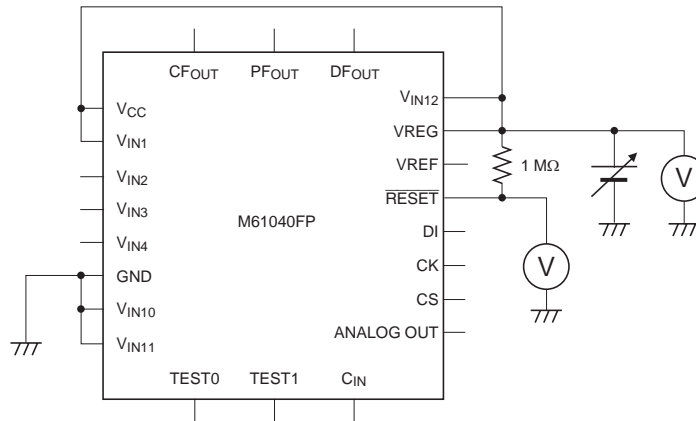
7. Conditioning circuit

M61040 have a discharge circuit of each cells. It is available for drop of cell voltage for safety purpose. And to shorten the difference voltage among the cells. It can extend the battery pack life.

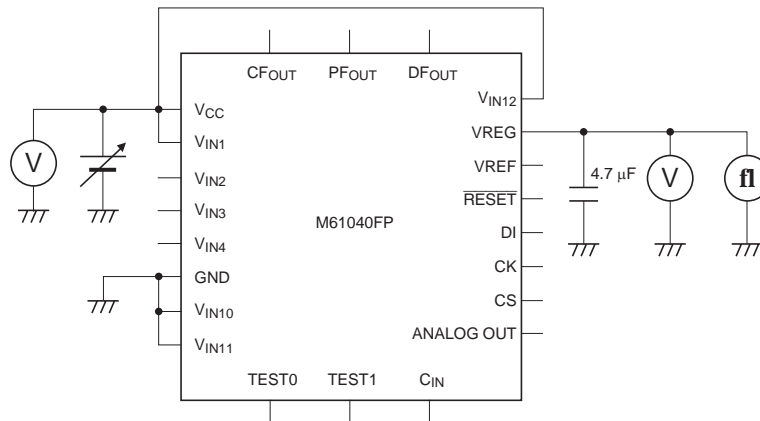
Measurement Circuit



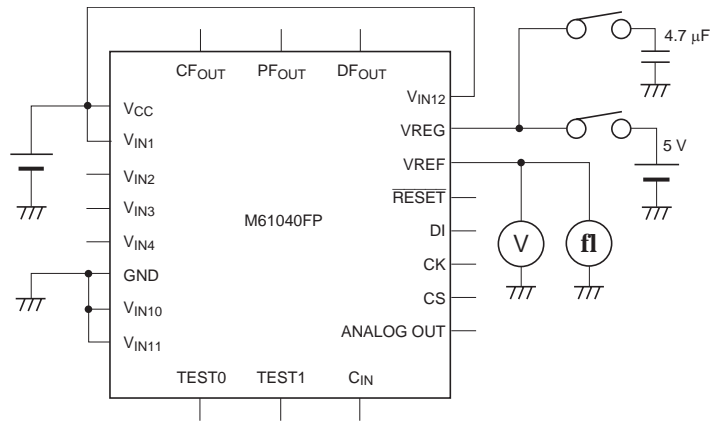
Circuit 1



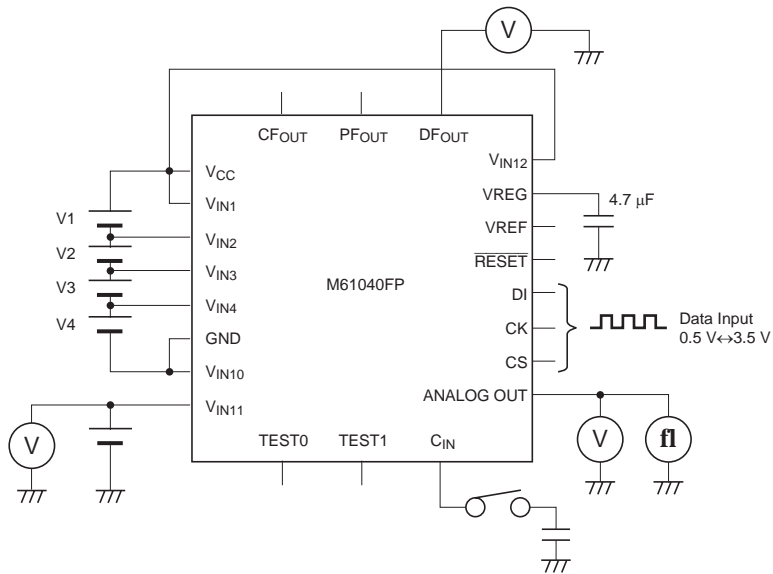
Circuit 2



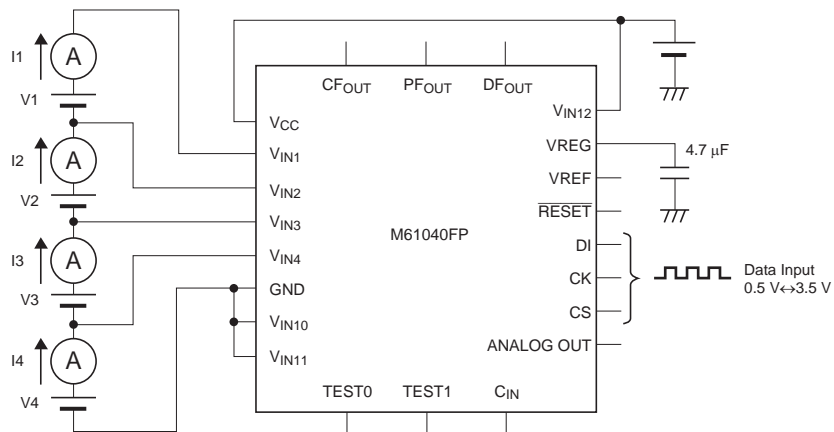
Circuit 3



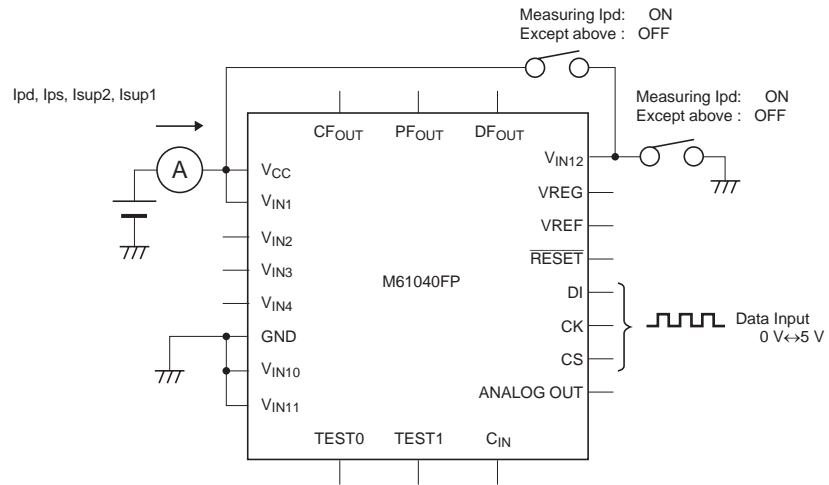
Circuit 4



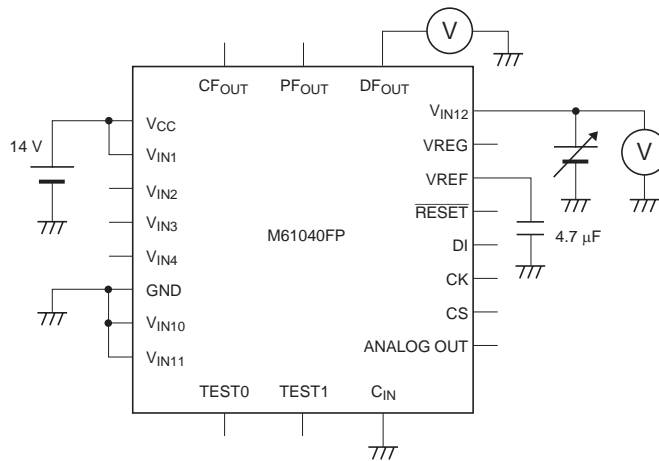
Circuit 5



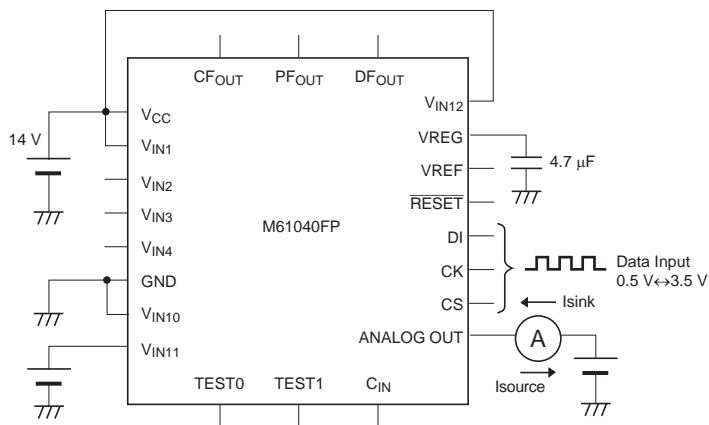
Circuit 6



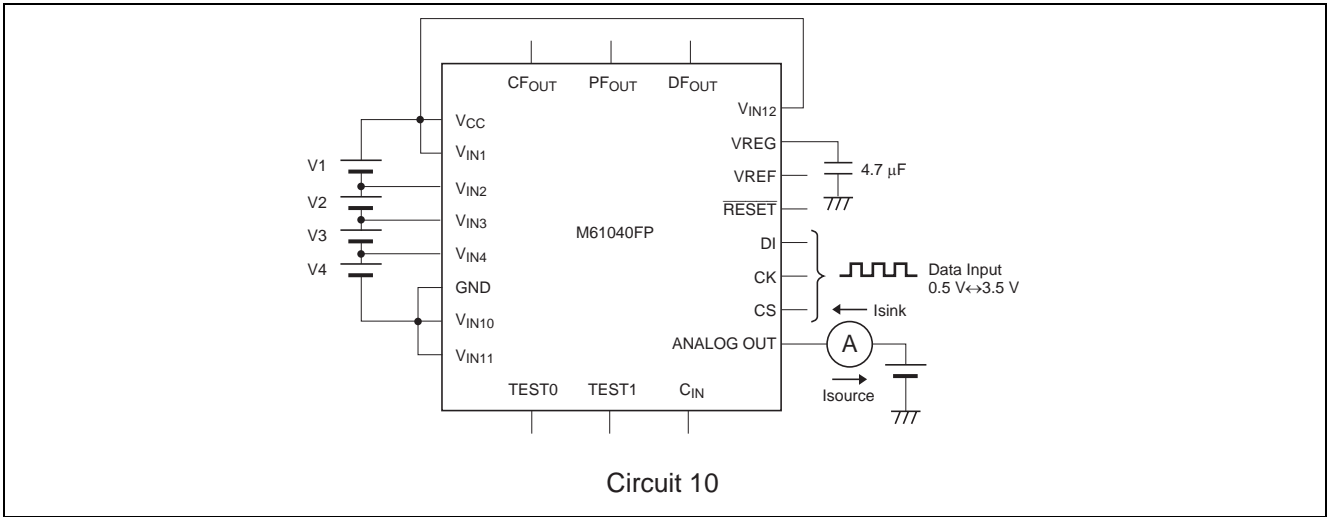
Circuit 7



Circuit 8



Circuit 9



Block Diagram Description

(1) Battery voltage detection circuit

The M61040 battery voltage detection circuit is shown in figure 3.

This circuit is composed of switch, buffer amplifier, reference voltage section and logic circuit.

Microcomputer selects detecting voltage before logic circuit controls the connection of switches. This connection decides which cell voltage (V_{bat1} , V_{bat2} , V_{bat3} , V_{bat4}) should be output from analog out pin. Besides offset voltage can be output.

In power down mode, supply current in this block is close to zero because all switches are off.

Note: Regard $50 \mu s$ as the standard of settling time by voltage change in this block.

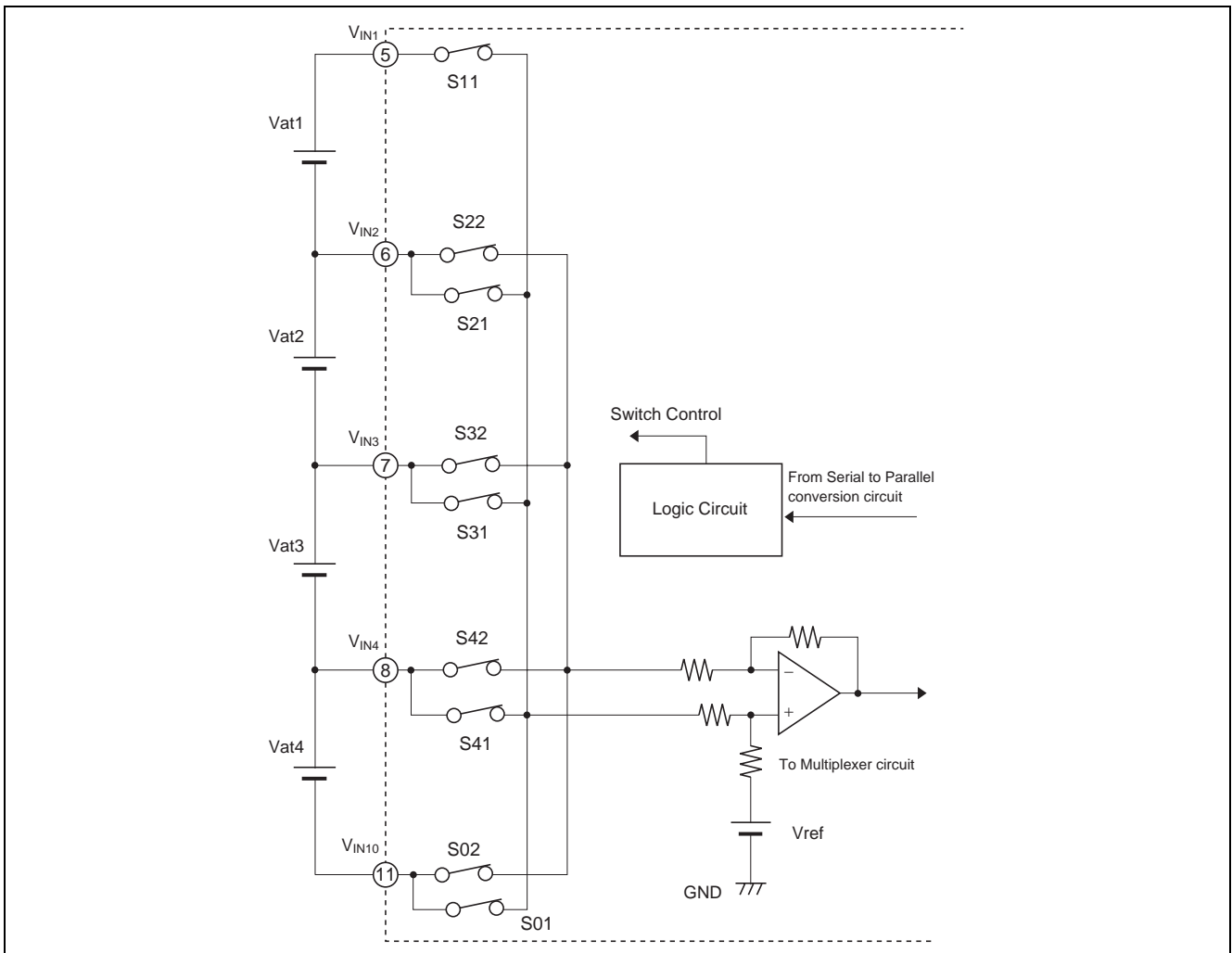


Figure 3 Battery Voltage Detection Circuit

(2) Charge/discharge current detection circuit

The charge/discharge current detection circuit is shown in figure 4. This circuit is composed of offset voltage adjustment circuit, buffer amplifier and resistor network.

The pre-amplifier amplifies the voltage of sense resistance to the voltage based on GND. The voltage gain can be selected by microcomputer commands.

Buffer amplifier does an impedance translation between input and output.

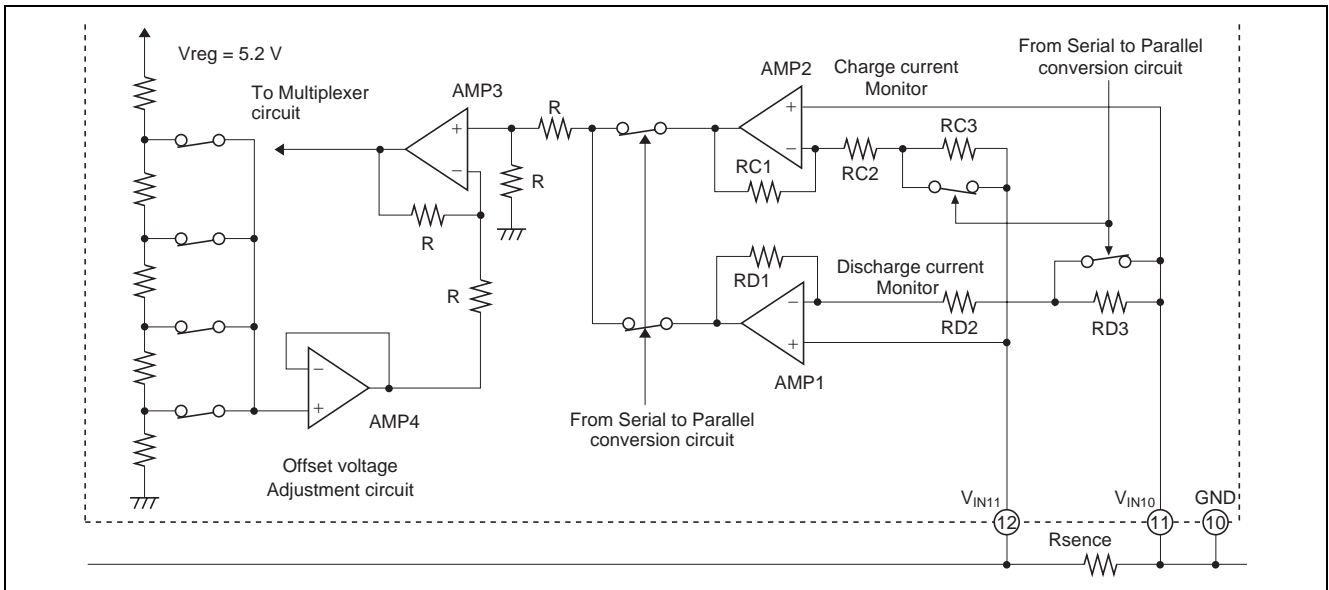


Figure 4 Charge/Discharge Current Detection Circuit

The offset voltage can be compensated by adjustment circuit.

The function in detecting discharge current is shown in figure 5. The differential voltage of sense resistor is input to + (plus) terminal of AMP 1 when discharge current is flowing in sense resistor. Selecting high voltage gain by microcomputer's command is capable of monitoring very little discharge current accurately.

The differential voltage of sense resistor is input to – (minus) terminal of AMP 2 when charge current is flowing in sense resistor. The methods of detecting in charging are the same as in discharging except that AMP2 reverses input voltage before outputting.

Note: Regard 500 μs as the standard of settling time by voltage change in this block.

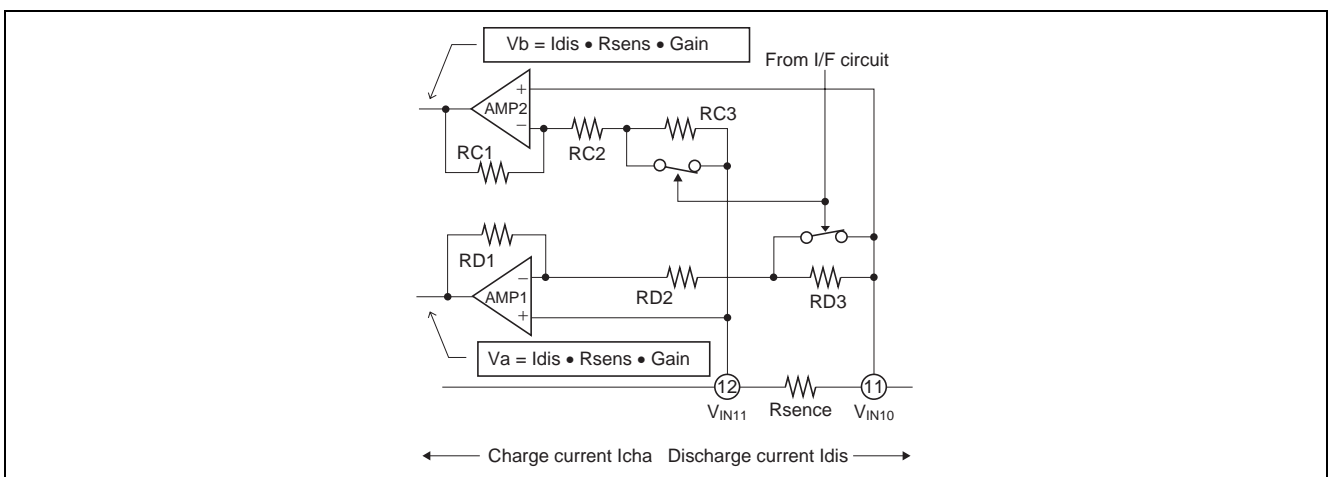


Figure 5 Charge/Discharge Current Detection

(3) Over current detection circuit

The over current detection circuit is shown in figure 6. This circuit is composed of comparator, reference voltage and delay circuit.

It can be got high accuracy over current detection by adjusting detection voltage with sense resistor. Microcomputer can detect the over current status through monitoring "C_{IN}" pin.

Besides this block contains load-short detection circuit. This circuit detects load-short with V_{IN12} pin and protects faster than over current detection.

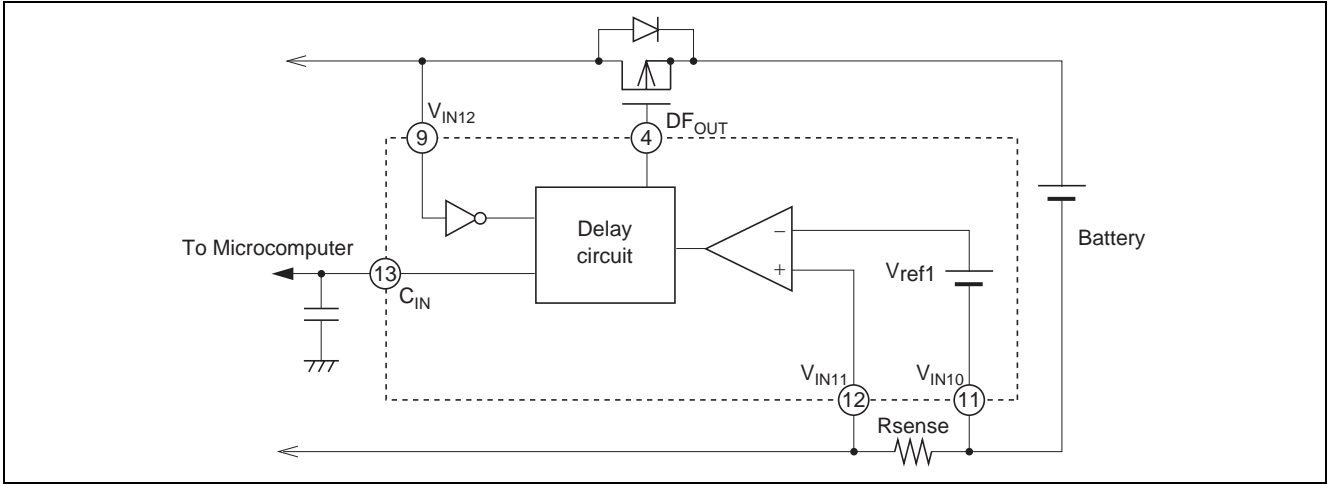


Figure 6 Over Current Detection Circuit

(4) Voltage regulator and reference voltage

Voltage regulator and reference circuit are shown in figure 7. Pch MOS transistor is used for output driver.

The output voltage can be adjusted by M61040 itself. So the external resistor is not required.

Note: There is a diode put between V_{CC} and Vreg terminal to prevent the invert current from damaging this IC when V_{CC} voltage is higher than Vreg voltage. So please always keep Vreg voltage lower than V_{CC} + 0.3 V. Set a condenser on output to suppress input changes or load changes.

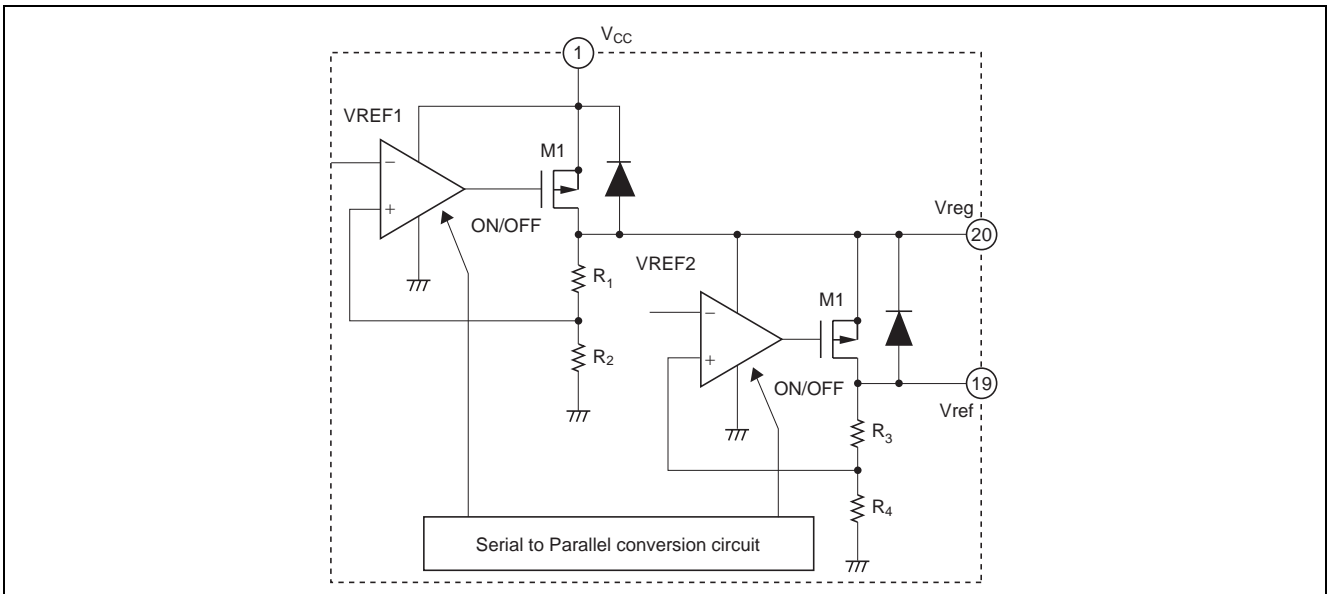


Figure 7 Voltage Regulator Circuit

(5) Reset circuit

The M61040 reset circuit is shown in figure 8. This circuit is composed of comparator, reference voltage section and breeder resistor.

The reset output is Nch open drain structure so the reset delay time depends on external CR value.

The reset circuit monitors Vreg output to prevent microcomputer abnormal operation when V_{CC} voltage goes down abnormally.

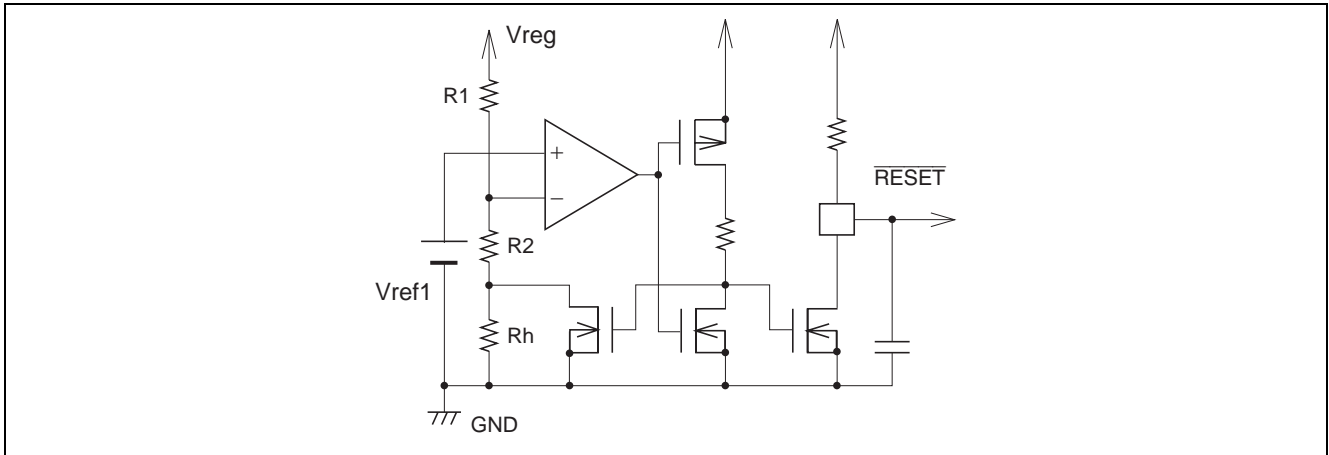


Figure 8 Reset Circuit

(6) Conditioning circuit

The M61040 conditioning circuit is shown in figure 9. This circuit is composed of switch, resistor and logic circuit. According to the serial data from microcomputer, the logic circuit can individually control the switches (S60, S61 ... etc.) to do individual cell discharge to a select voltage.

This circuit is capable of making all sells discharge at the same time.

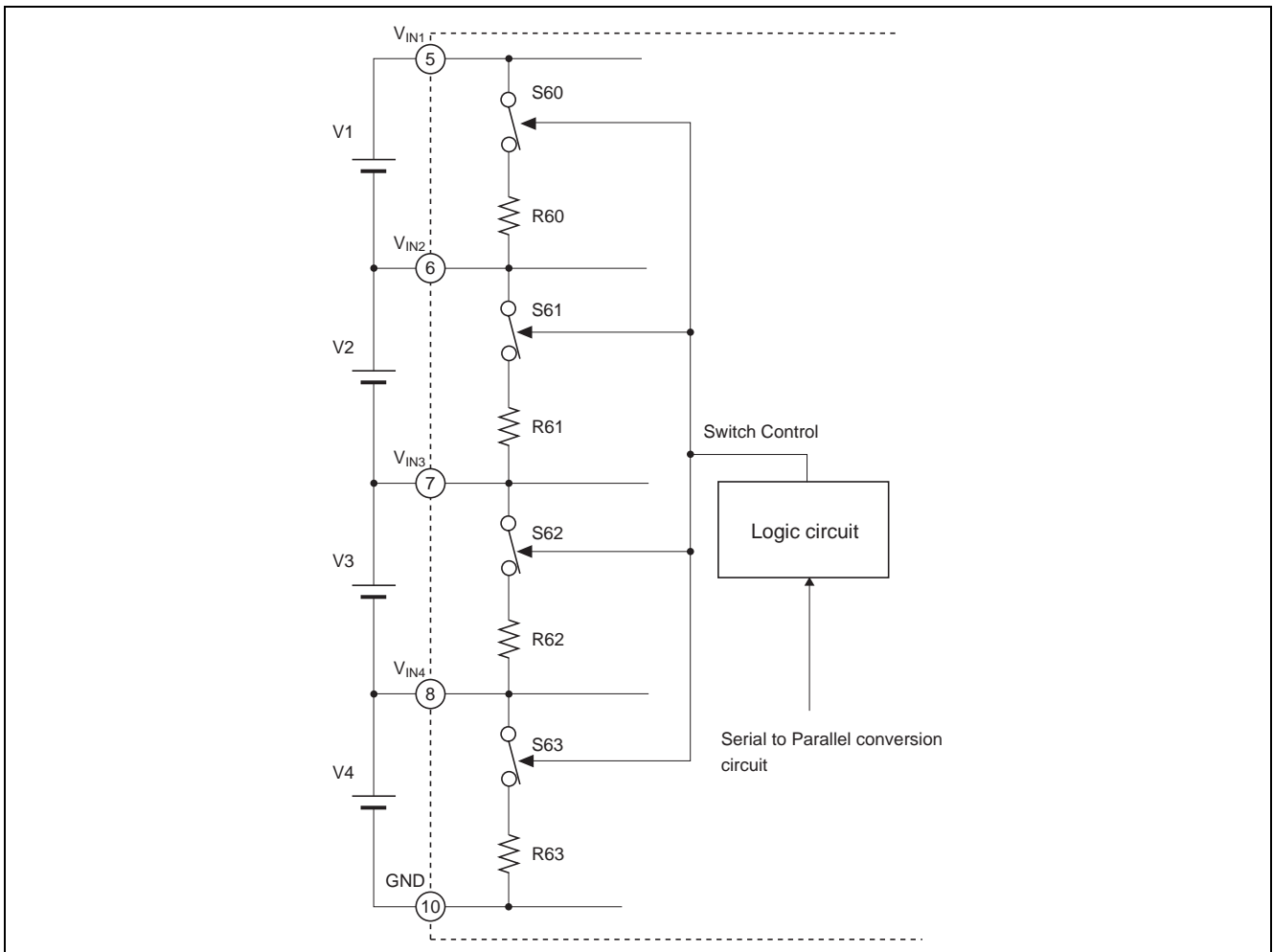


Figure 9 Conditioning Circuit

Digital Data Format

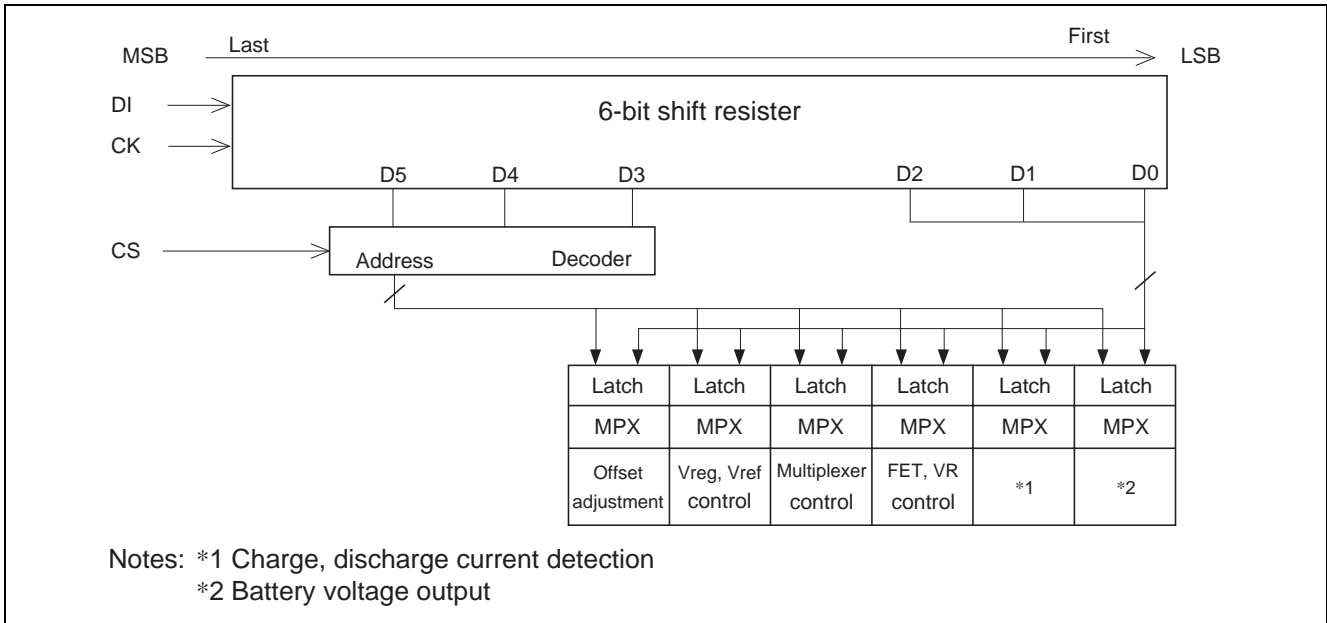


Figure 10 Serial to Parallel Conversion Circuit

Data Timing Example

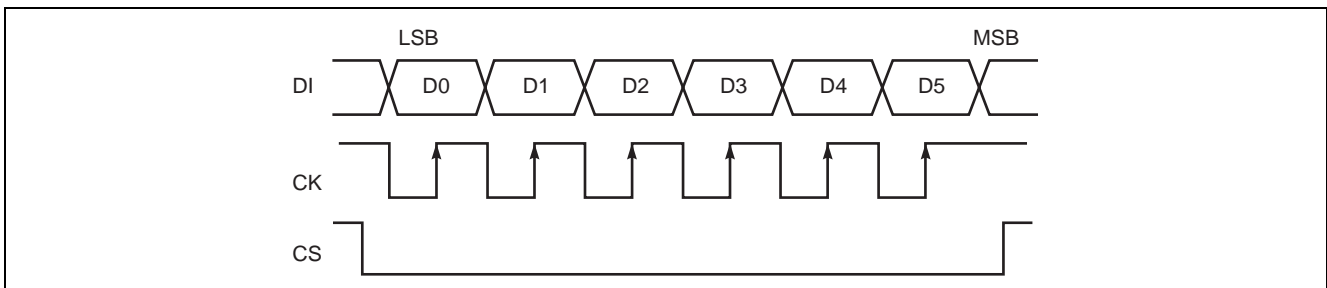


Figure 11 Serial to Parallel Timing Chart

Data Timing

Table 2

Establishment Data	Address			Data			Contents
	D5	D4	D3	D2	D1	D0	
Reset	0	0	0	—	—	—	
Battery voltage output	0	0	1	—	—	—	Refer to table 3
Offset adjustment	0	1	0	—	—	—	Refer to table 4
Charge/discharge current detection	0	1	1	—	—	—	Refer to table 5
FET control	1	0	0	—	—	—	Refer to table 6
Multiplexer select	1	0	1	—	—	—	Refer to table 7
Conditioning circuit	1	1	0	—	—	—	Refer to table 8
Regulator over current control	1	1	1	—	—	—	Refer to table 9

Table 3 Battery Voltage Output

D2	D1	D0	Output Voltage	Detail
0	0	0	V1	
0	0	1	V2	
0	1	0	V3	
0	1	1	V4	
1	0	0	Connect to V_{IN2}	Offset voltage output
1	0	1	Connect to V_{IN3}	Offset voltage output
1	1	0	Connect to V_{IN4}	Offset voltage output
1	1	1	Connect to V_{IN10}	Offset voltage output

Note: V1 battery voltage output when system reset

Table 4 Offset Voltage Control Section of Discharge Current Monitor Amplifier

D2	D1	D0	Output
			Offset Voltage Value
0	0	0	No offset (0 V)
0	0	1	1 V
0	1	0	2.1 V
0	1	1	3.1 V
1	0	0	3.7 V
1	0	1	1 V
1	1	0	1 V
1	1	1	1 V

Note: No offset voltage when system reset

Table 5 Charge and Discharge Current Detection

D2	D1	D0	Mode	Output
0	0	0	AMP stop, resistor open	AMP operation stop, current save
0	0	1	Gain × 40 output	
0	1	0	Gain × 100 output	
0	1	1	Gain × 200 output	
1	0	0	AMP stop, resistor open	AMP operation stop, current save
1	0	1	Offset output (× 40)	
1	1	0	Offset output (× 100)	
1	1	1	Offset output (× 200)	

Note: Amplifier operation is stopped when system reset

Table 6 FET Regulator Control

D2	D1	D0	FET Connection Terminal		
			CF _{OUT} Terminal	DF _{OUT} Terminal	PF _{OUT} Terminal
0	0	0	High	High	High
0	0	1	High	High	Low
0	1	0	High	Low	High
0	1	1	High	Low	Low
1	0	0	Low	High	High
1	0	1	Low	High	Low
1	1	0	Low	Low	High
1	1	1	Low	Low	Low

Note: CF_{OUT}, DF_{OUT} and PF_{OUT} are high when system reset. (Over current detection is disable when DF_{OUT} is high.)

Table 7 Multiplexer Control

D2	D1	D0	Output
0	0	0	Open output (floating) select
0	0	1	Open output (floating) select
0	1	0	Open output (floating) select
0	1	1	Open output (floating) select
1	0	0	Charge current output select
1	0	1	Discharge current output select
1	1	0	Battery voltage output select
1	1	1	GND output select

Note: Multiplexer output is floating when system reset

Table 8 Conditioning Circuit

D2	D1	D0	Output
0	0	0	Open
0	0	1	V1 conditioning (short V _{IN1} and V _{IN2})
0	1	0	V2 conditioning (short V _{IN2} and V _{IN3})
0	1	1	V3 conditioning (short V _{IN3} and V _{IN4})
1	0	0	V4 conditioning (short V _{IN4} and GND)
1	0	1	V1 to V4 conditioning (discharge all cells)
1	1	0	Open
1	1	1	Open

Note: Conditioning circuit is floating when system reset

Table 9 Regulator, Over Current Detection Control

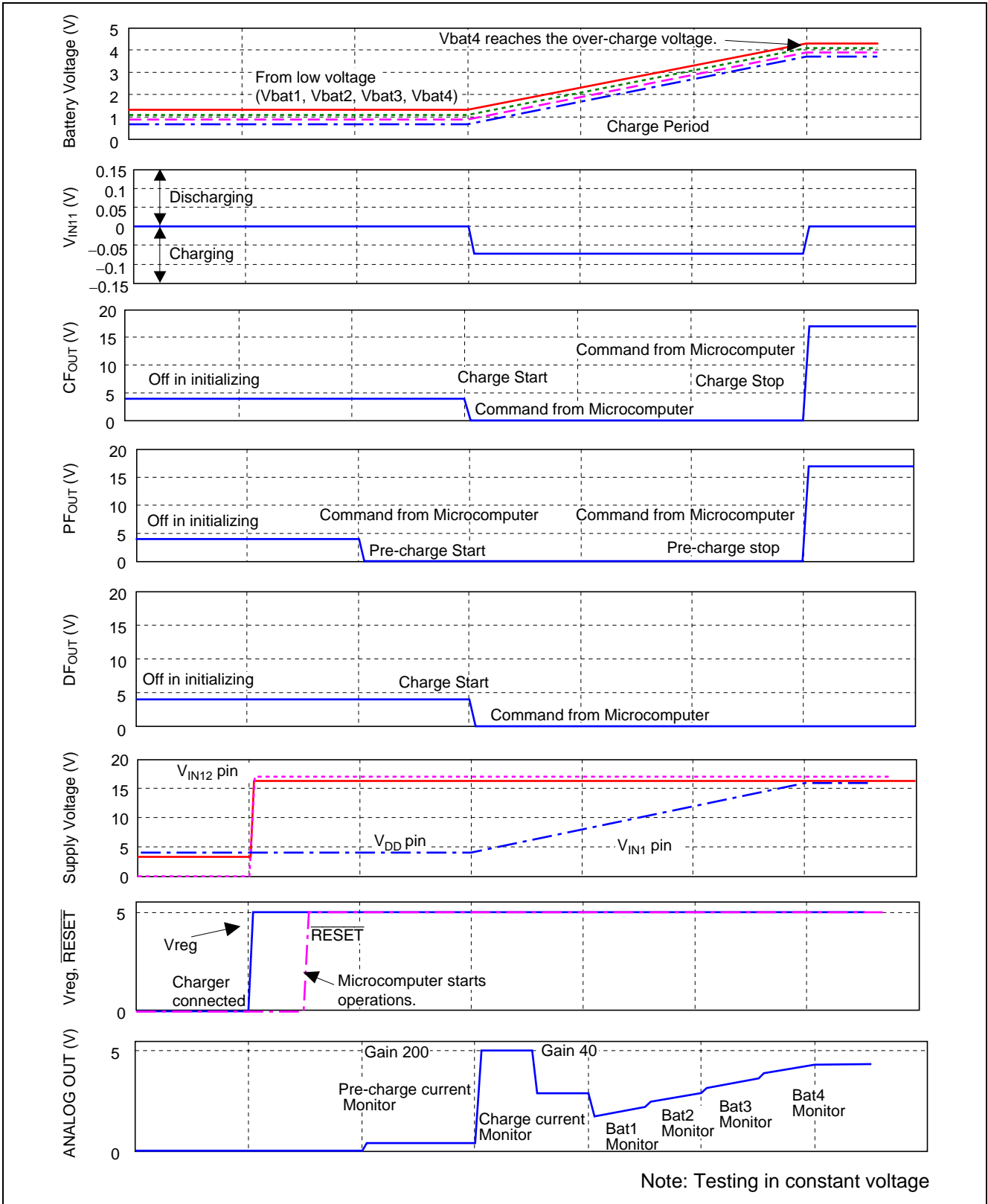
D2	D1	D0	Output	
			Regulator	Over Current Detection Circuit
0	0	0	ON	ON
0	0	1	OFF (GND output) *1	*1
0	1	0	ON	Capacity delay terminal L fix
0	1	1	ON	Capacity delay terminal H fix
1	0	0	Don't care	Don't care
1	0	1	Don't care	Don't care
1	1	0	Don't care	Don't care
1	1	1	Don't care	Don't care

Note: The regulator output is enable when system reset.

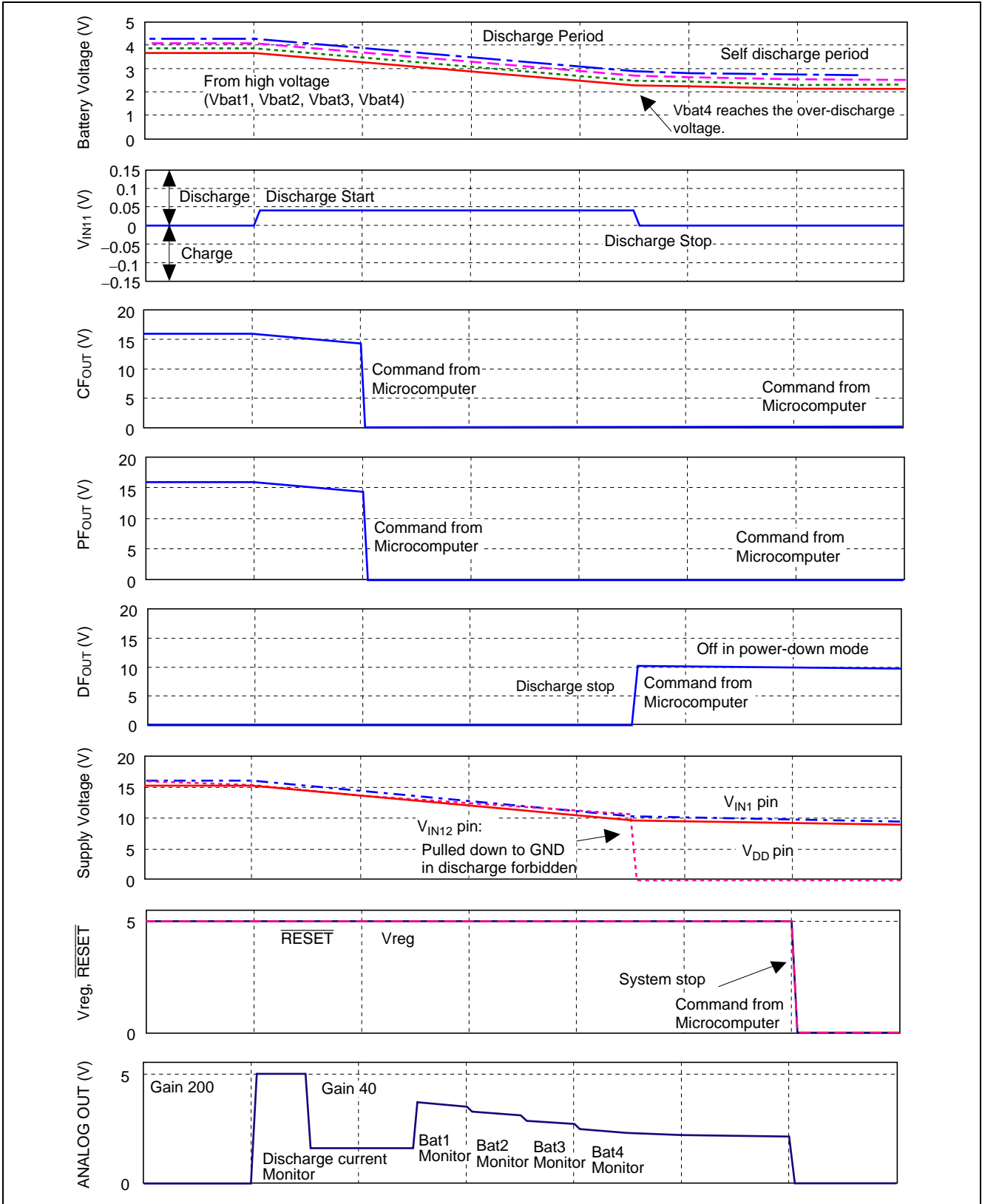
- All functions of M61040 are stooped. But if the charger is connected then M61040 will not enter power down mode.

Timing Chart

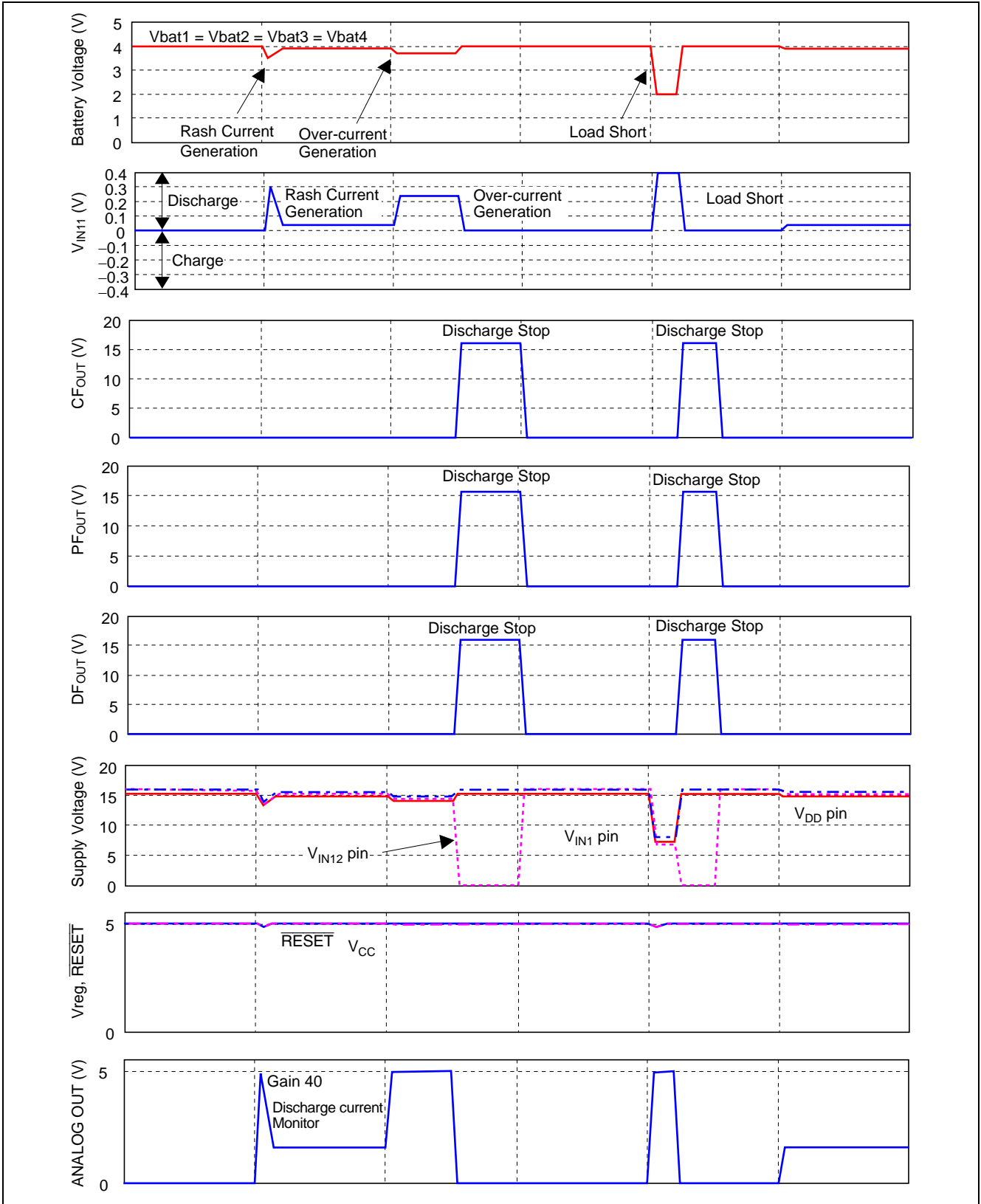
Discharge Sequence



Discharge Sequence



Over Current Detection Sequence



Application Circuit

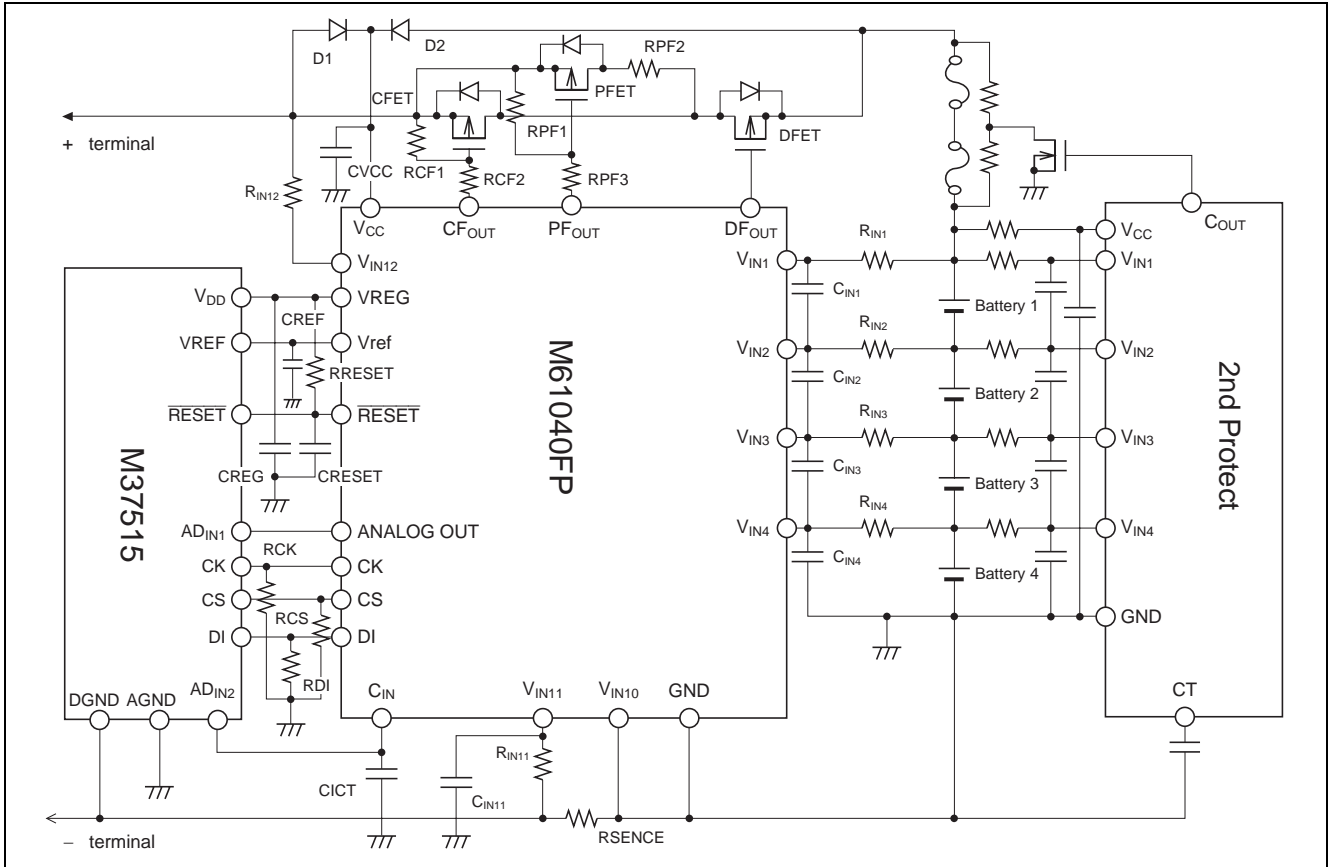


Table 10 Fixed Number

Symbol	Components	Purpose	Recommend	Min	Max	N.B.
D1	Diode	Supply voltage	—	—	—	Please take care the maximum power dissipation.
D2	Diode	Supply voltage	—	—	—	Please take care the maximum power dissipation.
DFET	Pch MOSFET	Discharge control	—	—	—	—
CFET	Pch MOSFET	Charge control	—	—	—	—
PFET	Nch MOSFET	Precharge control	—	—	—	—
RCF1	Resistor	Pull down resistor	1 M Ω	100 k Ω	3 M Ω	—
RCF2	Resistor	Current limit	100 k Ω	—	1 M Ω	—
RPF1	Resistor	Pull down resistor	1 M Ω	100 k Ω	3 M Ω	—
RPF2	Resistor	Precharge current control	1 k Ω	—	—	—
RPF3	Resistor	Current limit	100 k Ω	—	1 M Ω	—
R _{IN1}	Resistor	Measure for ESD	10 Ω	—	1 k Ω	—
C _{IN1}	Capacitor	Measure for ripples of power supply	0.22 μ F	—	1.0 μ F	
R _{IN2}	Resistor	Measure for ESD	1 k Ω	—	10 k Ω	—
C _{IN2}	Capacitor	Measure for ripples of power supply	0.22 μ F	—	1.0 μ F	
R _{IN3}	Resistor	Measure for ESD	1 k Ω	—	10 k Ω	Please set up same value as RIN2, CIN2
C _{IN3}	Capacitor	Measure for ripples of power supply	0.22 μ F	—	1.0 μ F	
R _{IN4}	Resistor	Measure for ESD	1 k Ω	—	10 k Ω	Please set up same value as RIN2, CIN2
C _{IN4}	Capacitor	Measure for ripples of power supply	0.22 μ F	—	1.0 μ F	
CICT	Capacitor	Set up delay time	0.01 μ F	—	0.47 μ F	—
R _{IN12}	Resistor	Measure for ESD	10 k Ω	300 Ω	200 k Ω	—
CV _{CC}	Capacitor	Measure for ripples of power supply	0.22 μ F	—	—	—
RSENCE	Sensing resistor	Charge/discharge current monitor	20 m Ω	—	—	—
R _{IN11}	Resistor	Measure for ripples of power supply	100 Ω	—	1 k Ω	—
C _{IN11}	Capacitor	Measure for ripples of power supply	0.1 μ F	—	1.0 μ F	
CREG	Capacitor	Eliminate the voltage noise	4.7 μ F	0.47 μ F	—	—
CREF	Capacitor	Eliminate the voltage noise	4.7 μ F	—	—	—
RRESET	Resistor	Set up delay time	47 k Ω	10 k Ω	3 M Ω	It is necessary that you adjust a delay time for MCU.
CRSET	Capacitor	Set up delay time	0.1 μ F	—	—	
RCK	Resistor	Pull down resistor	—	100 k Ω	—	—
RCS	Resistor	Pull down resistor	—	100 k Ω	—	—
RDI	Resistor	Pull down resistor	—	100 k Ω	—	—

Package Dimensions

20P2X-A

Note: Please contact Renesas Technology Corp. for further details.

Notes:

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