CONFIDENTIAL B

Fuel Gauge Application Notes

ACS/ACS1

Revision History

Revision	Date (mm/dd/yyyy)	Author	Comments
V1.0	07/05/2013	Lijian/Ricky/Pengchen	First version for customer.
V1.2	16/06/2016	Zhangshuai Zhang	Modify CAR_TUNE_VALUE calibration current

Agenda

- Preface
- HW Fuel gauge Application Notes(MT6589/6732/52/95)
  - Design without Fuel Gauge Function
  - Design with Default ZCV table
  - Design with Measure ZCV table
  - Fuel Gauge Test Way Introduction
- SW Fuel Gauge Application Notes(MT6572/82/92)
  - Design with Default ZCV table
  - Design with Measure ZCV table method
  - Fuel Gauge Test Way Introduction

Preface

File name	File address	File description
Fuel Gauge introduce	MediaTek DCC > External Document > HW > Common Design Notes > PMU > Fuel Gauge > Fuel Gauge introduce	The principle and algorithm of Fuel Gauge
Fuel Gauge Application Notes	MediaTek DCC > External Document > HW > Common Design Notes > PMU > Fuel Gauge >Fuel Gauge Application Notes	Importing the parameter & Testing method
Fuel Gauge Battery ZCV Table Test SOP_V1.0	MediaTek DCC > External Document > HW > Common Design Notes > PMU > Fuel Gauge > Fuel Gauge Battery ZCV Table Test SOP_V1.0_20120716.pptx	Testing method of ZCV table

HW Fuel gauge Application Notes

Agenda

- Design without Fuel Gauge Function
- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Agenda

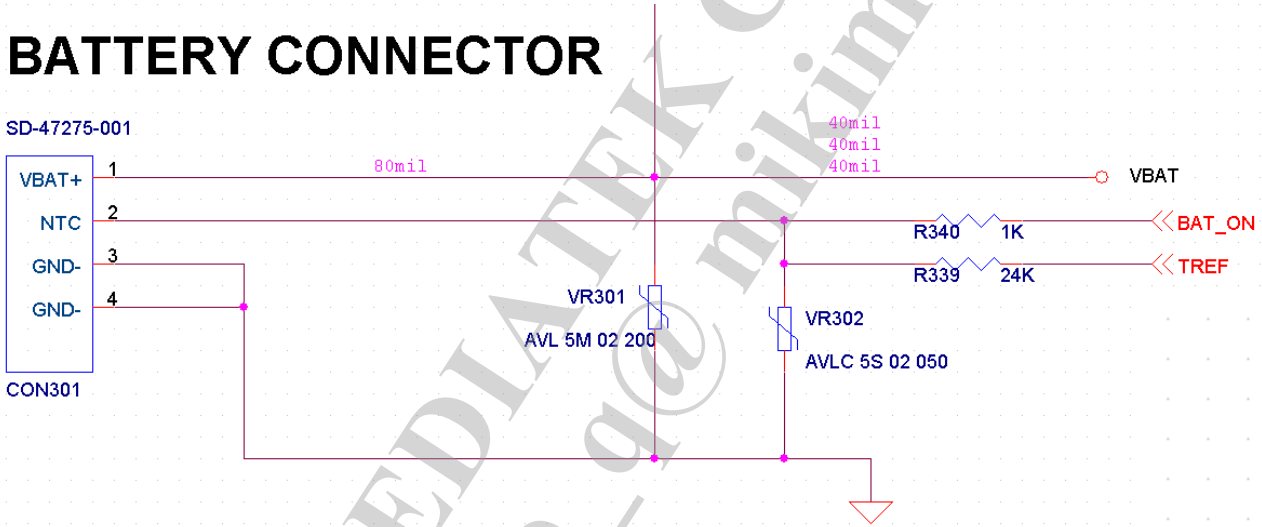
- **Design without Fuel Gauge Function**
- **Design with Default ZCV table**
- **Design with Measure ZCV table**
- **Fuel Gauge Test Way Introduction**

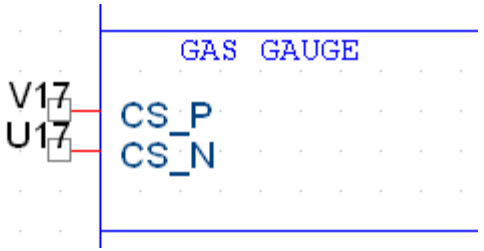
Design without Fuel Gauge Function

Case of Customer Support		Customers	Pros	Cons	Effort
No Use Fuel Gauge		1. For Cost down (remove Rfg) 2. Do not case the battery percentage	Remove Rfg (< 0.03US)	Battery percentage error rate = 30%~50%	None
Use MTK Fuel Gauge	**Use default ZCV Table**	1. Need precise battery percentage 2. Can not get the battery ZCV table	1. Battery percentage error rate < 20% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)	Need Use default ZCV Table	Need Rfg (< 0.01US)
	MTK SA measure ZCV Table for each customer	**1.Need precise battery percentage 2. Can get the battery ZCV table**	**1. Battery percentage error rate <10% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)**	**Need 3 weeks for creating the ZCV table**	**1. Need Rfg (< 0.01US) 2. Need provide the battery packet and SPEC to MTK SA for creating the ZCV table. (same as the flow of Gas Gauge IC vender)**

Design without Fuel Gauge Function

- If don't use the Fuel gauge function，you could choose the traditional battery indicator method，Reference design as follows：
  1. Rfg remove，The GND of battery connector should be directly connected to the system GND；
  2. CS_P/CS_N No Connection 。





Agenda

- Design without Fuel Gauge Function
- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Design with Default ZCV table

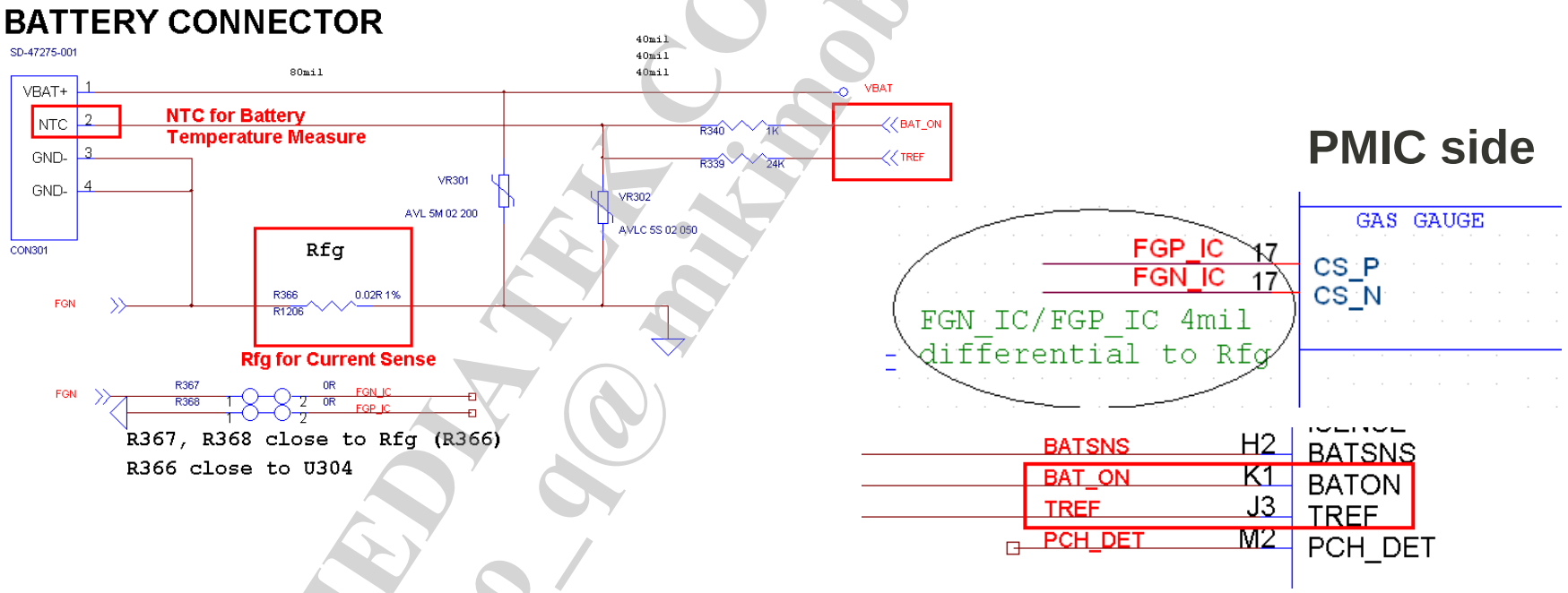
Case of Customer Support		Customers	Pros	Cons	Effort
No Use Fuel Gauge		1. For Cost down (remove Rfg) 2. Do not case the battery percentage	Remove Rfg (< 0.03US)	Battery percentage error rate = 30%~50%	None
Use MTK Fuel Gauge	Use default ZCV Table	1. Need precise battery percentage 2. Can not get the battery ZCV table	1. Battery percentage error rate < 20% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)	Need Use default ZCV Table	Need Rfg (< 0.01US)
	MTK SA measure ZCV Table for each customer	**1.Need precise battery percentage 2. Can get the battery ZCV table**	**1. Battery percentage error rate <10% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)**	**Need 3 weeks for creating the ZCV table**	**1. Need Rfg (< 0.01US) 2. Need provide the battery packet and SPEC to MTK SA for creating the ZCV table. (same as the flow of Gas Gauge IC vender)**

HW condition to enable Fuel gauge(must)

- Battery temperature detection circuit is a must
  - Note: Fuel gauge will monitor battery temperature and do algorithm compensation via temperature parameter, so battery temperature detection function is a must. NTC resistor value may choose 10Kohm@25 ℃ or 47Kohm@25 ℃, if another NTC resistor value is used, customer need to built the NTC temperature table.
- Must use 20~50mohm current detection resistor
  - Note: Recommend choose 20mohm, so withstand current up to 3.5A and decrease voltage drop. According to $P=I_2*R$, the lower resistor value will lower the power demand. As for the package of Rfg, it depends PCB dimension, but must meet the Power demand.
- Fuel gauge Schematics design and PCB layout must meet the design requirement.
  - Please refer to next two pages

Fuel gauge Reference Design

- 1： Rfg placement must be close to battery connector
- 2： FGP_IC/FGN_IC must layout in differential pair, and be ground shielding well.

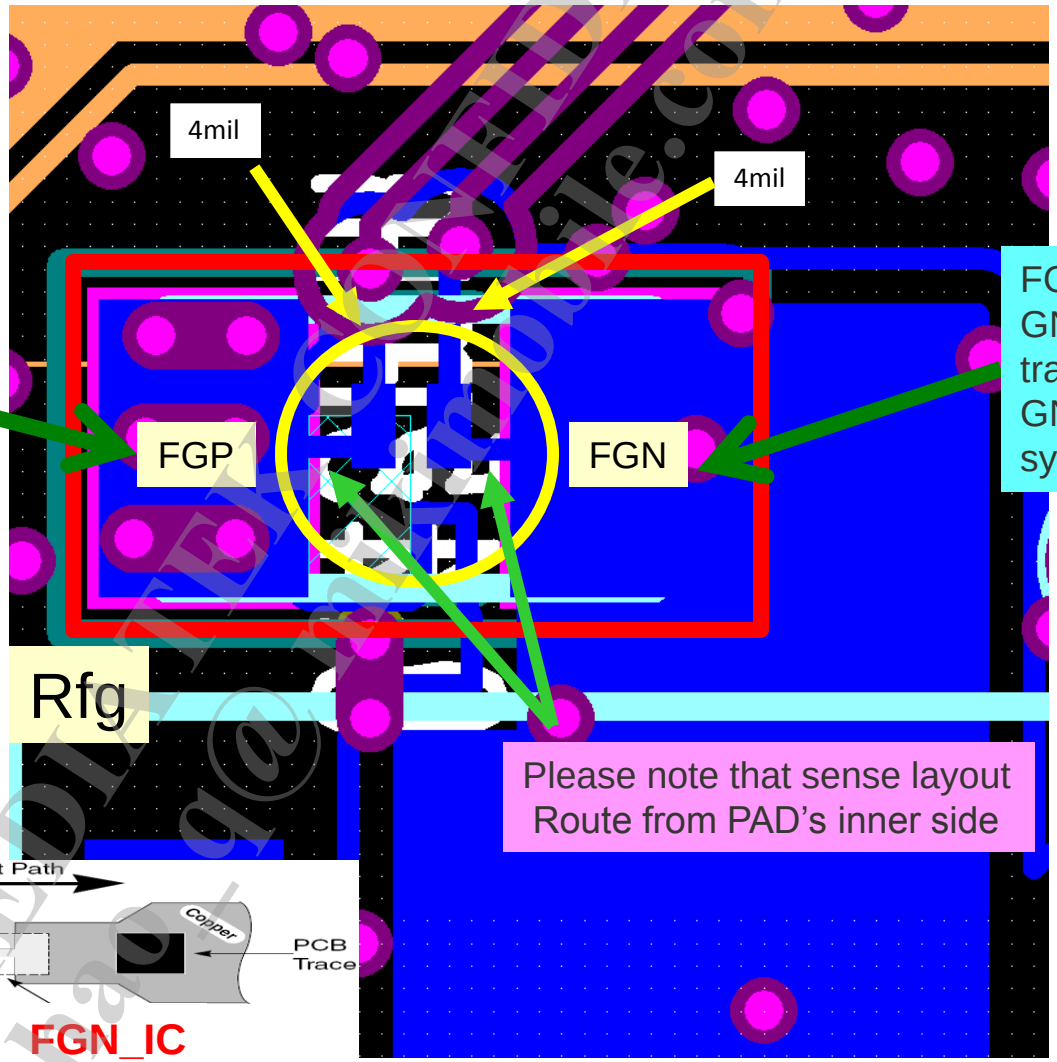


Fuel gauge Layout FGN_IC/FGP_IC

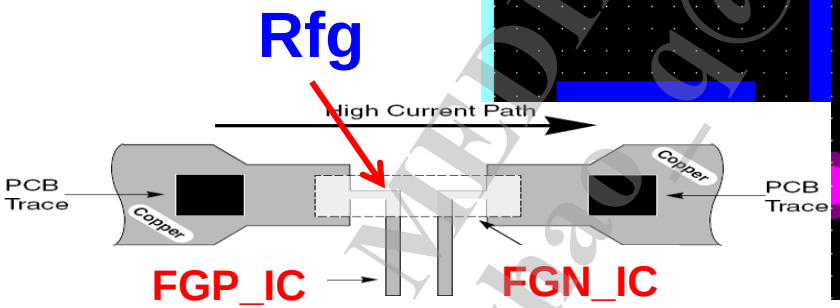
Gas Gauge recommend Layout

FGP as systemGND Need enough VIA to system GND So as to withstand system power current

FGN as BATTERY GND Need enough trace width toBATTERY GND So as towithstand system power current



Please note that sense layout Route from PAD's inner side



Customization file preparation

- The cust_fuel_gauge.h file needs to be modified for customization.

- Note: The default battery capacity is 1100mAh@MT6575, if you choose the battery capacity large different with 1100mAh, you need to adjust the relative battery capacity parameter.
- Because customization is based on our default ZCV table, the deviation of battery gauge's initial capacity will become a little big, but that will not influence Fuel gauge statistics deviation when using. And initial capacity deviation will auto calibration after a full charged or full discharged.

Customization of Max Battery Capacity

- Note: In addition to items need to be modified below, please don't modify other parameter, or it may result in abnormity.
- 1： According to battery datasheet, confirm the max battery capacity(or nominal capacity), then define the value as BATTERY_CAPACITY_MAXIMUM and BATT_CAPACITY.
- For example: if battery capacity is 1500mAh(below we all take 1500mAh as example)

```
47  #define BATTERY_VOLTAGE_MINIMUM          3400
48  #define BATTERY_VOLTAGE_MAXIMUM          4200
49
50  #define BATTERY_CAPACITY_MAXIMUM         1500
51
52  #define TEMPERATURE_T0                   110
53  #define TEMPERATURE_T1                   0
54  #define TEMPERATURE_T2                   25
55  #define TEMPERATURE_T3                   50
57
58  //#define BATT_CAPACITY                  1280
59  #define BATT_CAPACITY                    1500
60
61  #define ENABLE_SW_COULOMB_COUNTER        0 // 1 is enable, 0 is disable
62  //#define ENABLE_SW_COULOMB_COUNTER       1 // 1 is enable, 0 is disable
63
```

Modify to 1500mAh

Modify to 1500mAh

Q_MAX Replacement

- 2： Fill in the Q_MAX for 50℃、25 ℃、0 ℃、-10 ℃.
  - Note:all data below take the integer portion.

```
89
90  #define Q_MAX_POS_50   1510
91  #define Q_MAX_POS_25   1500
92  #define Q_MAX_POS_0    1400
93  #define Q_MAX_NEG_10   1334
94
95  #define Q_MAX_POS_50_H_CURRENT   1486
96  #define Q_MAX_POS_25_H_CURRENT   1458
97  #define Q_MAX_POS_0_H_CURRENT    1265
98  #define Q_MAX_NEG_10_H_CURRENT   687
99
100 #define R_FG_VALUE         20 // mOhm, base is 20
101 #define CURRENT_DETECT_R_FG 100  //10mA
102
```

Here change to: nominal capacity ×(1316/1307)

Here change to battery nominal capacity(ex.1500mAh)

Here change to: nominal capacity×(1220/1307)

Here change to: nominal capacity ×(1162/1307)

Here change to: nominal capacity×(1295/1307)

Here change to: nominal capacity× (1270/1307)

Here change to: nominal capacity×(1102/1307)

Here change to: nominal capacity×(599/1307)

Rfg Replacement

- 3： If the value of Rfg is not 20mohm, need to change R_FG_VALUE to the value you choose. Just modify the resistor value to your choose value. If is 20mohm, no need to change.

```
100
101 #define R_FG_VALUE        20 // mOhm, base is 20
102 #define CURRENT_DETECT_R_FG 100  //10mA
103
104 #define OSR_SELECT_7      0
105
```

- 4： Because we use Default ZCV Database , relevant Database array no need to modify, use directly.

CAR_TUNE_VALUE Adjustment

- CAR_TUNE_VALUE is used to correct the Fuel gauge statistics deviation, to make sure the Fuel gauge statistical accuracy. This CAR_TUNE_VALUE is mainly influenced by Rfg PCB layout and SMT consistency, so every project need to modify CAR_TUNE_VALUE.
  - Application Suggestion: For CAR_TUNE_VALUE will apply to all Mobiles in the same project, suggest that select 10 mobiles randomly, calculate each mobile's CAR_TUNE_VALUE, then sum and average for 10 mobile's CAR_TUNE_VALUE, then use the average value as final CAR_TUNE_VALUE and write to SW code.
  - The way to modify CAR_TUNE_VALUE, please refer: page 34-37 .

```
103
104  #define OSR_SELECT_7     0
105
106  #define CAR_TUNE_VALUE      104 //1.04
107
108  ////////////////////////////////////////////////
109  // <DOD, Battery_Voltage> Table
110  ////////////////////////////////////////////////
```

Fuel gauge Test

- After complete customization modification aforementioned, you can verify the Fuel gauge according to your own testing method. Because haven't testing ZCV table as reference, the Fuel gauge testing method is decided by customer.
- Testing note:
  - 1: Fuel gauge only read battery temperature , battery voltage and Rfg current when booting, to calculate OCV(Open Circuit Voltage), then table look-up to get battery gauge percentage.
  - 2: After mobile boot up, Fuel gauge use Coulomb Counter to integrate over Rfg current, and get the battery capacity.
  - 3: For better user experience, our software have many tracking methods, tracking methods please refer The Fuel gauge Part in Design Notice . Avoid puzzling everybody.

Agenda

- Design without Fuel Gauge Function
- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Design with Measure ZCV table

Case of Customer Support		Customers	Pros	Cons	Effort
No Use Fuel Gauge		1. For Cost down (remove Rfg) 2. Do not case the battery percentage	Remove Rfg (< 0.03US)	Battery perce error rate 30%~50%	
Use MTK Fuel Gauge	**Use default ZCV Table**	1. Need precise battery percentage 2. Can not get the battery ZCV table	1. Battery percentage error rate < 20% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)	Need Use defau ZCV Table	
	MTK SA measure ZCV Table for each customer	**1.Need precise battery percentage 2. Can get the battery ZCV table**	**1. Battery percentage error rate <10% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)**	**Need 3 weeks for creating the ZCV table**	**1. Need Rfg (< 0.01US) 2. Need provide the battery packet and SPEC to MTK SA for creating the ZCV table. (same as the flow of Gas Gauge IC vender)**

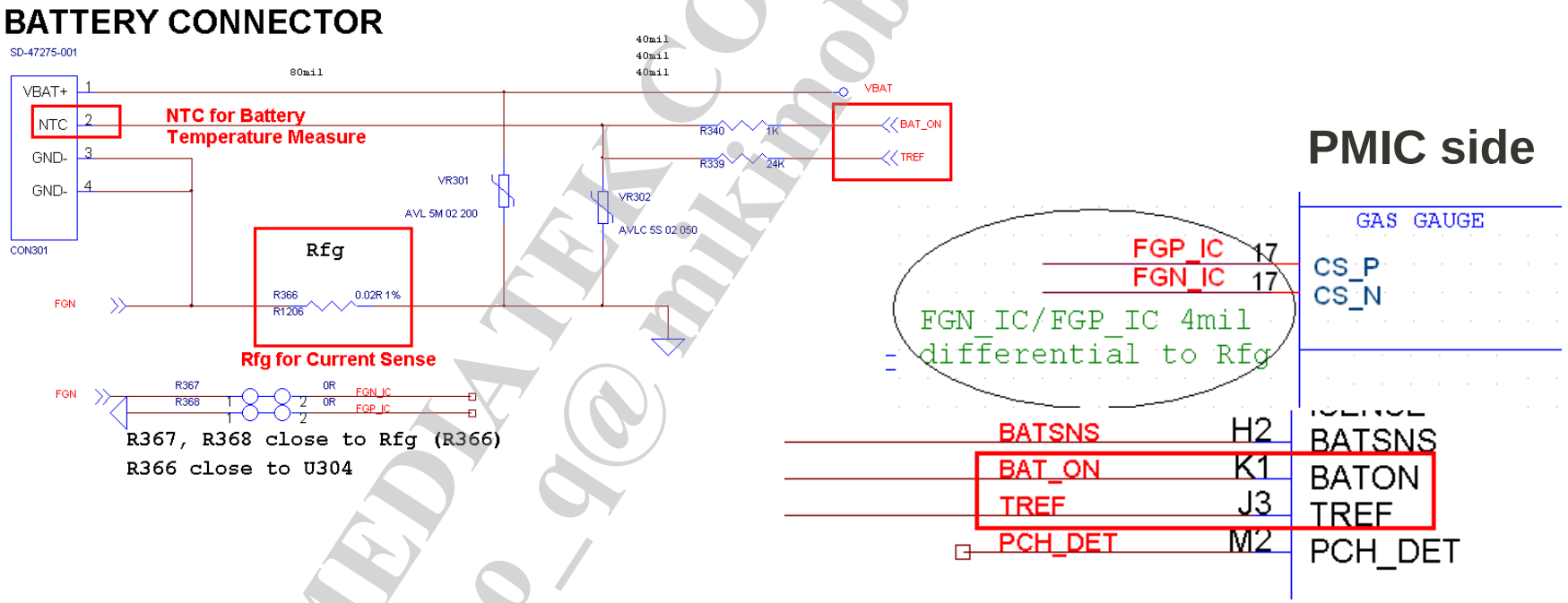
Fuel gauge battery ZCV table testing demand, please contact CPM

HW condition to enable Fuel gauge(must)

- Battery temperature detection circuit is a must
  - Note: Fuel gauge will monitor battery temperature and do algorithm compensation via temperature parameter, so battery temperature detection function is a must. NTC resistor value may choose 10Kohm@25degree or 47Kohm@25degree, if another NTC resistor value is used, customer need to built the NTC temperature table.
- Must use 20~50mohm current detection resistor
  - Note: Recommend choose 20mohm, so withstand current up to 2.5A and decrease voltage drop. According to $P=I^2*R$, the lower resistor value will lower the power demand. As for the package of Rfg, it depends PCB dimension, but must meet the Power demand.
- Fuel gauge Schematics design and PCB layout must meet the design requirement.
  - Please refer to next two page

Fuel Gauge Reference Design

- 1: Rfg placement must be close to battery connector
- 2: FGP_IC/FGN_IC layout in differential pair, ground shielding, up and down, left and right.

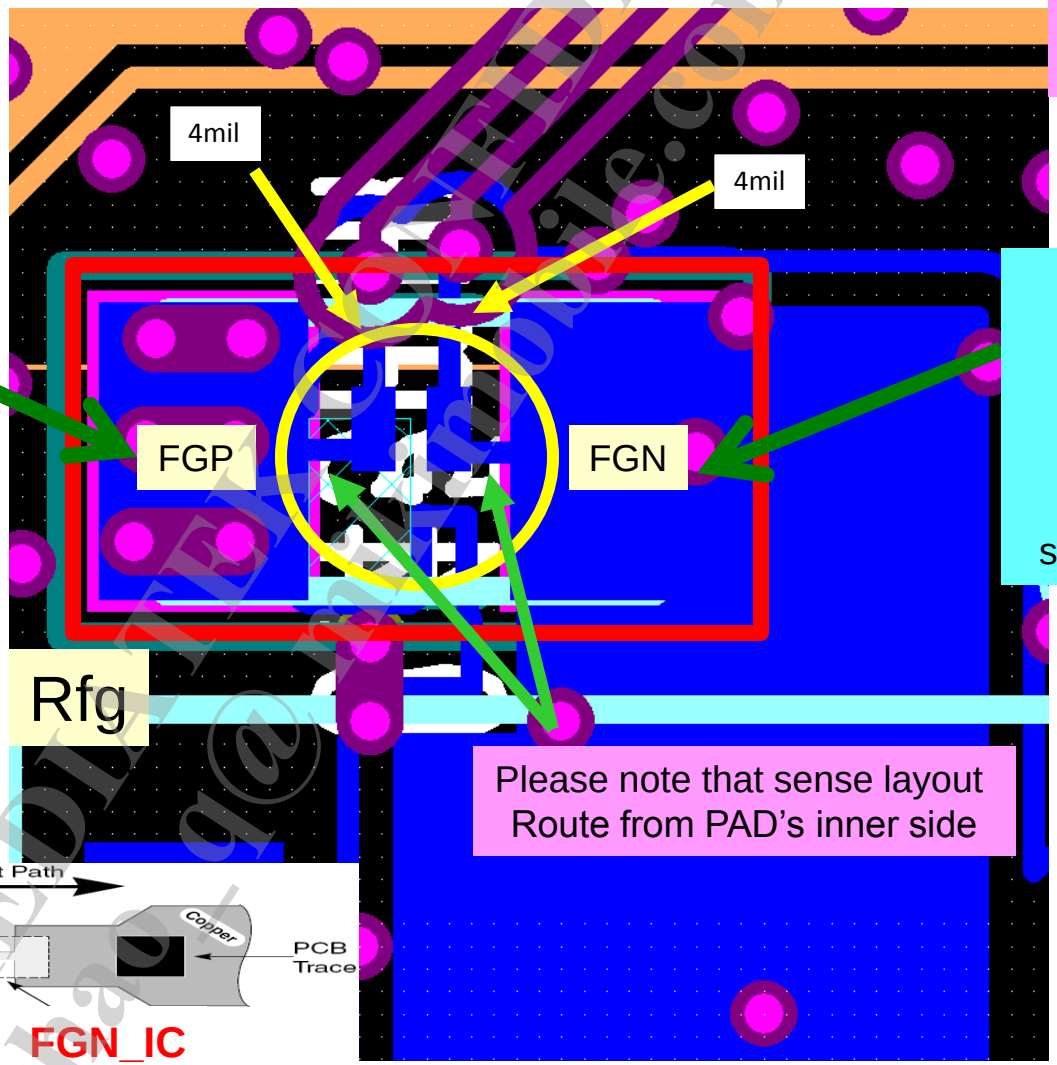


Fuel gauge Layout FGN_IC/FGP_IC

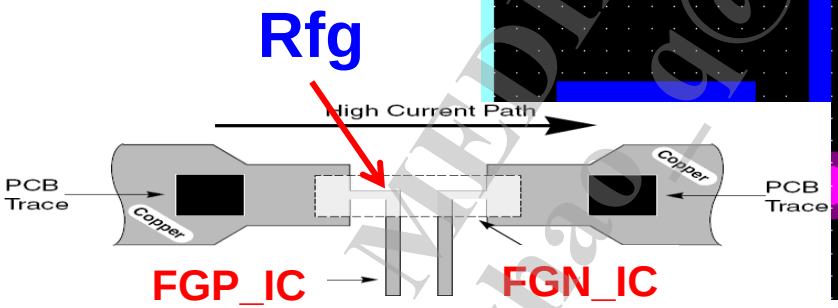
Gas Gauge
recommend Layout

FGP as system GND
Need enough VIA to system GND
So as to withstand system power current

FGN as BATTERY GND
Need enough trace width to BATTERY GND
So as to withstand system power current



Please note that sense layout
Route from PAD's inner side



Fill in material preparation

- Customer provide 3pcs bran-new original battery and battery datasheet for MTK testing, after testing, MTK will feedback ZCV table of XXXX @2012xxxx.xlsx file.
- The custom_fuel_gauge.h file need to fill ZCV data.

How to fill ZCV Data

- **Note: In addition to items need to be modified below, please don't modify other parameter, or it may result in abnormity.**
- 1: Use the Cmax testing in 50°C to replace original BATTERY CAPACITY MAXIMUM, define it as battery max available capacity.

```
48  #define BATTERY_VOLTAGE_MAXIMUM          4200
49
50  #define BATTERY_CAPACITY_MAXIMUM         1497
51
52  #define TEMPERATURE_TO                   110
```

50度	OCV	VC	mAh
	4188		0
	4167	4109	30

Cmax		1497
Cmax_400mA		1485

Cmax Replacement

- 2: Use the Cmax testing in 25℃ to replace original BATTERY CAPACITY MAXIMUM, define it as battery available capacity in normal temperature, or nominal capacity.

25度	OCV	VC	mAh
	4182		0
	4160	4089	30
	4142	4070	60

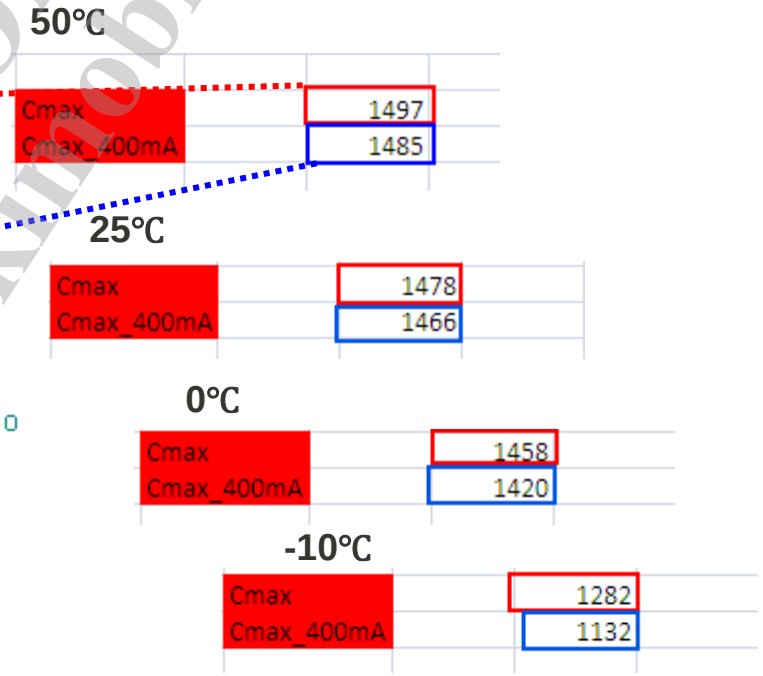
```
58  //#define BATT_CAPACITY                 1280
59  #define BATT_CAPACITY                 1478
60
61  #define ENABLE_SW_COULOMB_COUNTER     0 // 1 is enable, 0 is disable
```

Cmax		1478	
Cmax_400mA		1466	

Q_MAX Replacement

- 3: Use the Cmax\Cmax_400mA testing in 50℃、25℃、0℃、-10℃ to replace original corresponding temperature Q_MAX value respectively.
  - Note: _H_CURRENT represent the battery discharging capacity in 400mA condition.

```
89
90  #define Q_MAX_POS_50   1497
91  #define Q_MAX_POS_25   1478
92  #define Q_MAX_POS_0    1458
93  #define Q_MAX_NEG_10   1282
94
95  #define Q_MAX_POS_50_H_CURRENT   1485
96  #define Q_MAX_POS_25_H_CURRENT   1466
97  #define Q_MAX_POS_0_H_CURRENT    1420
98  #define Q_MAX_NEG_10_H_CURRENT   1132
99
100 #define R_FG_VALUE         20 // mOhm, base is 20
101 #define CURRENT_DETECT_R_FG 100  //10mA
```



Rfg Replacement

- 4: If the value of Rfg is not 20mohm, need to change R_FG_VALUE to the value you choose. Just modify the resistor value to your choose value. If is 20mohm, no need to change.

```
100
101  #define R_FG_VALUE        20 // mOhm, base is 20
102  #define CURRENT_DETECT_R_FG 100  //10mA
103
104  #define OSR_SELECT_7      0
105
```

ZCV Database replace <DOD,OCV>

- 5-1: ZCV Database replacement, use the data in different temperature, 50℃, 25℃, 0℃, -10℃, respectively, to replace original data. <DOD,OCV>

```
// <DOD, Battery_Voltage> Table
123   // T0 -10C
124   BATTERY_PROFILE_STRUC battery_profile_t0[] =
125   {
126     {0  , 4174},
127     {2  , 4158},
128     {5  , 4112},
129     {7  , 4074},
130     {9  , 4053},
131     {12 , 4038},
132     {14 , 4023},
133     {16 , 3998},
134     {19 , 3958},
135     {21 , 3941},
136     {23 , 3933},
137     {26 , 3922},
138     {28 , 3910},
139     {30 , 3897},
140     {33 , 3881},
141     {35 , 3867},
142     {37 , 3854},
143     {40 , 3842},
144     {42 , 3833},
145     {44 , 3824},
146     {47 , 3818},
147     {49 , 3812},
148     {51 , 3806},
149     {54 , 3801},
150     {56 , 3798},
151     {58 , 3793},
162     {84 , 3728},
163     {86 , 3721},
164     {88 , 3714},
165     {91 , 3709},
166     {93 , 3700},
167     {95 , 3674},
168     {98 , 3600},
169     {99 , 3550},
170     {99 , 3522},
171     {100, 3506},
172     {100, 3496},
173     {100, 3489},
174     {100, 3485},
175     {100, 3482},
176     {100, 3479},
177     {100, 3477},
178     {100, 3476},
179     {100, 3474},
180     {100, 3473},
181     {100, 3400},
182     {100, 3400},
183     {100, 3400},
184     {100, 3400}
185   };
186
```

負10度	OCV	VC	mAh	R(battery)	DOD	R(x1000)
	4174		0	0.34	0	340
	4158	4022	30	0.34	2	340
	4112	3976	60	0.34	5	340
	4074	3938	90	0.34	7	340
	4053	3918	119	0.3375	9	338
	4038	3899	149	0.3475	12	348
	4023	3875	179	0.37	14	370
	3998	383			16	413
	3958	372			19	578
	3941	367			21	678
	3933	3648	298	0.7125	23	713
	3922	3634	328	0.72	26	720
	3910	3621	358	0.7225	28	723
	3897	3607	388	0.725	30	725
	3881	3596	418	0.7125	33	713
	3867	3583	448	0.71	35	710
	3854	3573	478	0.7025	37	703
	3842	3563	507	0.6975	40	698
	3833	3554	537	0.6975	42	698
	3824	3545	567	0.6975	44	698
	3818	3537	597	0.7025	47	703
	3812	3530	627	0.705	49	705
	3806	3523	657	0.7075	51	708
	3801	3516	686	0.7125	54	713
	3798	3509	716	0.7225	56	723
	3793	3502	746	0.7275	58	728
	3791	3498	776	0.7325	61	733
	3788	3496	806	0.73	63	730

OCV： Open Circuit Voltage

DOD :Depth of Discharge

Note: the last pair data in the array haven't "," symbol, comma symbol.

ZCV Database replace <DOD,OCV>

- 5-2: If data length in ZCV table isn't equal to array length in code. Just adjust the array length in SW code, let it equal the data length in ZCV table. Exp:184-125=60-1=59, so adjust all array length to 59, including {0,0} array.

```
123  // T0 -10C
124  BATTERY_PROFILE_STRUC battery_profile_t0[] =
125  {
126      {0  , 4174},
127      {2  , 4158},
128      {5  , 4112},
129      {7  , 4074},
130      {9  , 4053},
131      {12 , 4038},
132      {14 , 4023},
133      {16 , 3998},
134      {19 , 3958},
135      {21 , 3941},
```

```
178      {100, 3476},
179      {100, 3474},
180      {100, 3473},
181      {100, 3400},
182      {100, 3400},
183      {100, 3400},
184      {100, 3400}
185  };
186
187  // T1 0C
```

1	負10度	OCV	VC	mAh	R(battery)	DOD	R(x1000)
2		4174		0	0.34	0	340
3		4158	4022	30	0.34	2	340
4		4112	3976	60	0.34	5	340
5		4074	3938	90	0.34	7	340
6		4053	3918	119	0.3375	9	338
7		4038	3899	149	0.3475	12	348
8		4023	3875	179	0.37	14	370
9		3998	3833	209	0.4125	16	413
10		3958	3727	239	0.5775	19	578
52		3479	3198	1281	0.7025	100	703
53		3477	3197	1281	0.7	100	700
54		3476	3199	1281	0.6925	100	693
55		3474	3195	1282	0.6975	100	698
56		3473	3196	1282	0.6925	100	693
57		3400	3193	1282	0.5175	100	518
58		3400	3193	1282	0.5175	100	518
59		3400	3193	1282	0.5175	100	518
60		3400	3193	1282	0.5175	100	518
61							
62							

ZCV Database replace <Rbat,OCV>

- 6:ZCV Database replacement, use the data in different temperature, 50℃, 25℃, 0℃, -10℃, respectively, to replace original data. <Rbat, OCV> , the method is the same as <DOD,OCV>, attention equal length of the array.

```
//////////////////////////////////////////
// <Rbat, Battery_Voltage> Table
//////////////////////////////////////////
528   // T0 -10C
529   R_PROFILE_STRUC r_profile_t0[] =
530   {
531     {340, 4174},
532     {340, 4158},
533     {340, 4112},
534     {340, 4074},
535     {338, 4053},
536     {348, 4038},
537     {370, 4023},
538     {413, 3998},
539     {578, 3958},
540     {678, 3941},
541     {713, 3933},
542     {720, 3922},
543     {723, 3910},
544     {725, 3897},
545     {713, 3881},
546     {710, 3867},
547     {703, 3854},
576     {770, 3506},
577     {745, 3496},
578     {728, 3489},
579     {718, 3485},
580     {710, 3482},
581     {703, 3479},
582     {700, 3477},
583     {693, 3476},
584     {698, 3474},
585     {693, 3473},
586     {518, 3400},
587     {518, 3400},
588     {518, 3400},
589     {518, 3400}
590   };
```

負10度	OCV	VC	mAh	R(battery)	DOD	R(x1000)
	4174		0	0.34	0	340
	4158	4022	30	0.34	2	340
	4112	3976	60	0.34	5	340
	4074	3938	90	0.34	7	340
	4053	3918	119	0.3375	9	338
	4038	3899	149	0.3475	12	348
	4023	3875	179	0.37	14	370
	3998	3833	209	0.4125	16	413
	3958	3727	239	0.5775	19	578
	3941	3670	269	0.6775	21	678
	3933	3648	298	0.7125	23	713
	3922	3634	328	0.72	26	720
	3910	3621	358	0.7225	28	723
	3897	3607	388	0.725	30	725
	3881	3596	418	0.7125	33	713
	3867	3583	448	0.71	35	710
	3854	3573	478	0.7025	37	703
	3842	3563	507	0.6975	40	698
	3833	3554	537	0.6975	42	698
	3824	3545	567	0.6975	44	698
	3818	3537	597	0.7025	47	703
	3812	3530	627	0.705	49	705

Note: the last pair data in the array haven't "," symbol, comma symbol.

CAR_TUNE_VALUE Adjustment

- 7: CAR_TUNE_VALUE is used to correct the Fuel gauge statistics deviation, to make sure the Fuel gauge statistical accuracy. This CAR_TUNE_VALUE is mainly influenced by Rfg PCB layout and SMT consistency, so every project need to modify CAR_TUNE_VALUE.
  - Application Suggestion: For CAR_TUNE_VALUE will apply to all Mobiles in the same project, suggest that select 10 mobiles randomly, calculate each mobile's CAR_TUNE_VALUE, then sum and average for 10 mobile's CAR_TUNE_VALUE, then use the average value as final CAR_TUNE_VALUE and write to SW code.
  - The way to modify CAR_TUNE_VALUE, please refer: page 35-38

```
103
104  #define OSR_SELECT_7     0
105
106  #define CAR_TUNE_VALUE      104 //1.04
107
108  ////////////////////////////////////////////////
109  // <DOD, Battery_Voltage> Table
110  ////////////////////////////////////////////////
```

Fuel gauge Test

- After complete the modification aforementioned, you can test battery gauge for verification according to Fuel Gauge Test Way Introduction. You can also do the verification using your own testing method.
- Testing note:
  - 1: Fuel gauge only read battery temperature , battery voltage and Rfg current when booting, to calculate OCV(Open Circuit Voltage), then table look-up to get battery gauge percentage.
  - 2: After mobile boot up, Fuel gauge use Coulomb Counter to integrate over Rfg current, and get the battery capacity.
  - 3: For better user experience, our software have many tracking methods, tracking methods please refer The Fuel gauge Part in Design Notice . Avoid puzzling everybody.

How to Modify CAR_TUNE_VALUE

- 1st step: Change #define CAR_TUNE_VALUE to 100, then build a version of the software, then for subsequent steps. (This step must carry out, or subsequent modification value will incorrect)

```
103
104  #define OSR_SELECT_7      0
105
106  #define CAR_TUNE_VALUE      100 //1.00
107
108  ////////////////////////////////////////////////////
109  // <DOD, Battery_Voltage> Table
110  ////////////////////////////////////////////////////
```

How to Modify CAR_TUNE_VALUE

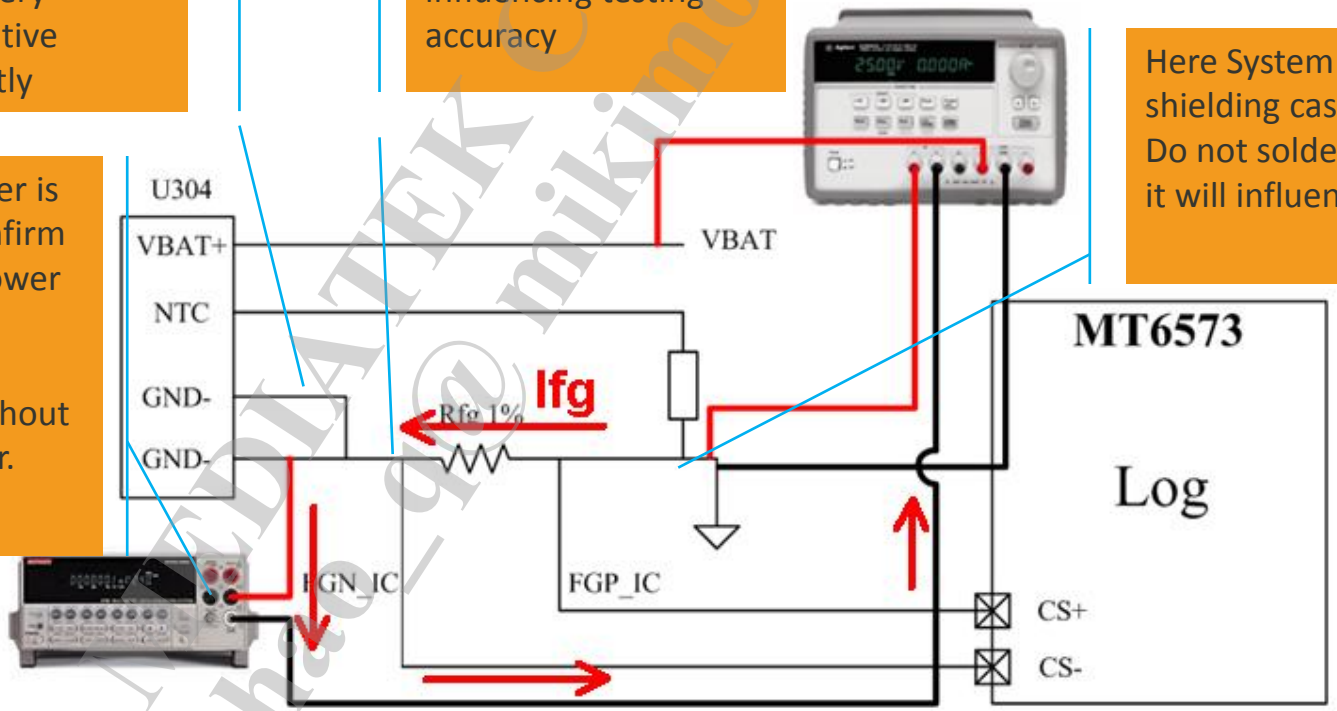
- 2nd step: Apply 3.8V between VBAT and System GND, power for mobile.
  - Note: the channel supply current for Rfg, please don't solder wires between Rfg, because solder wire will influence Rfg resistor value. So connect the wire to random system GND(such as shielding case), and battery connector negative electrode.

Here when testing connection, please connect to battery connector negative electrode directly

Note: Please do not Re-work to Rfg, avoid influencing testing accuracy

Here amperemeter is mainly use to confirm current.If your power supply precise enough(1mA accuracy),can without this amperemeter.

Here System GND can be shielding case, T-card GND, Do not solder wire from Rfg, it will influence result.



How to Modify CAR_TUNE_VALUE

- 3rd step: Connect System GND to power supply another channel's positive electrode, then apply a amperemeter between this channel's negative electrode and battery connector GND. Attention current direction and polarity when connect.
  - Note: when connect, please confirm the channel voltage is 0V, avoid damaging the amperemeter. If your power supply can display current value accurately, can without amperemeter, directly use the display current value. Please don't solder wires between Rfg, so connect the wire to random system GND(such as shielding case), and battery connector negative electrode.
- 4th step: Set power supply to CC mode, limit the output current to 1000mA, use the amperemeter to confirm actual current. If power supply can't support CC mode, your can adjust the output voltage of power supply, let the amperemeter value to 1000mA .(recommend CC mode)
  - Note: when confirm the current, don't move the testing circuit, avoid current changing and read error.

How to Modify CAR_TUNE_VALUE

- 5th step: Press power key letting the phone on, enter operation GUI, select dial UI, input engineering mode code *#*#3646633#*#* enter engineering mode. Then select Power->Charge Battery ,read 5th row, FG_Battery_CurrentConsumption to get current value Ifg。
- 6th step: Then divide 1000mA by Ifg, correct CAR_TUNE_VALUE=1000/Ifg. Exp: Ifg=1064mA,that is 94, the third of the decimal rounding operation.(this value is reasonable no matter Greater than or less than 100)

```
100  #define R_FG_VALUE        20 // mOhm, base is 20
101  #define CURRENT_DETECT_R_FG 100  //10mA
102
103  #define OSR_SELECT_7       1
104
105  #define CAR_TUNE_VALUE     94 //0.94
106
107  ////////////////////////////////////////////////////
```

Back to Page 17

Back to Page 32

Agenda

- Design without Fuel Gauge Function
- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Agenda

- Test equipment requirements
- D0 precision test
- Fuel gauge ADC Current precision test

Test equipment requirements

- High precision Voltmeter
  - Accurately measuring the battery voltage, Accuracy is more than ±0.1mV。
  - Example： Keithley 2700
    - Note： The accuracy of the voltage measurement affects the accuracy of the test。

D0 precision test 1/4

Attention to the temperature 25℃

- Step 1： Put the battery in the phone and have it full charged，then take it out.
  - Note： Gauge show100%， then take out the battery.（Please take out the battery in 10 mins after full charged）
    - Show battery percent： Settings->About phone->Status->Battery level
- Step 2： Take out the battery and make it stay in inactive state for 30 mins， measure the battery voltage and record $V_{battery}$.
  - For example： $V_{Battery}$ =4.17644V

D0 precision test 2/4

Attention to the temperature 25℃

- Step 3： Accordding to $V_{battery,}$Look up the ZCV curve and find the percentage D_ZCV(Look-up table method),get the actual battery percentage（A%）and record it.
  - $V_{Battery}$=4.17644V,using the look-up table method to get the actual percentage.
    - 4.17644V is between 4.188V and 4.175V， We can calculate the real percentage in MTK provided ZCV table is 99.10125%（A%）.Attention to the normal temperature,please refer to 25℃ ZCV table.

25度	OCV	VC	mAh	R(battery)	DOD
	4188		0		0
	4175	4113	20	0.155	1
	4162	4100	40	0.155	3
	4147	4086	60	0.1525	4
	4134	4074	80	0.15	5
	4122	4062	100	0.15	7
	4111	4050	120	0.1525	8
	4099	4038	140	0.1525	9

常温驗證	x1(max)	x2(min)	y1(DOD)	y2(DOD)	y(result)
	4188	4175	0	1	0.889231
					99.11077
				指示百分	99.10125
			30分钟之	4.17644	

注意：常温下測試，查表請參考25度時量測的ZCV表

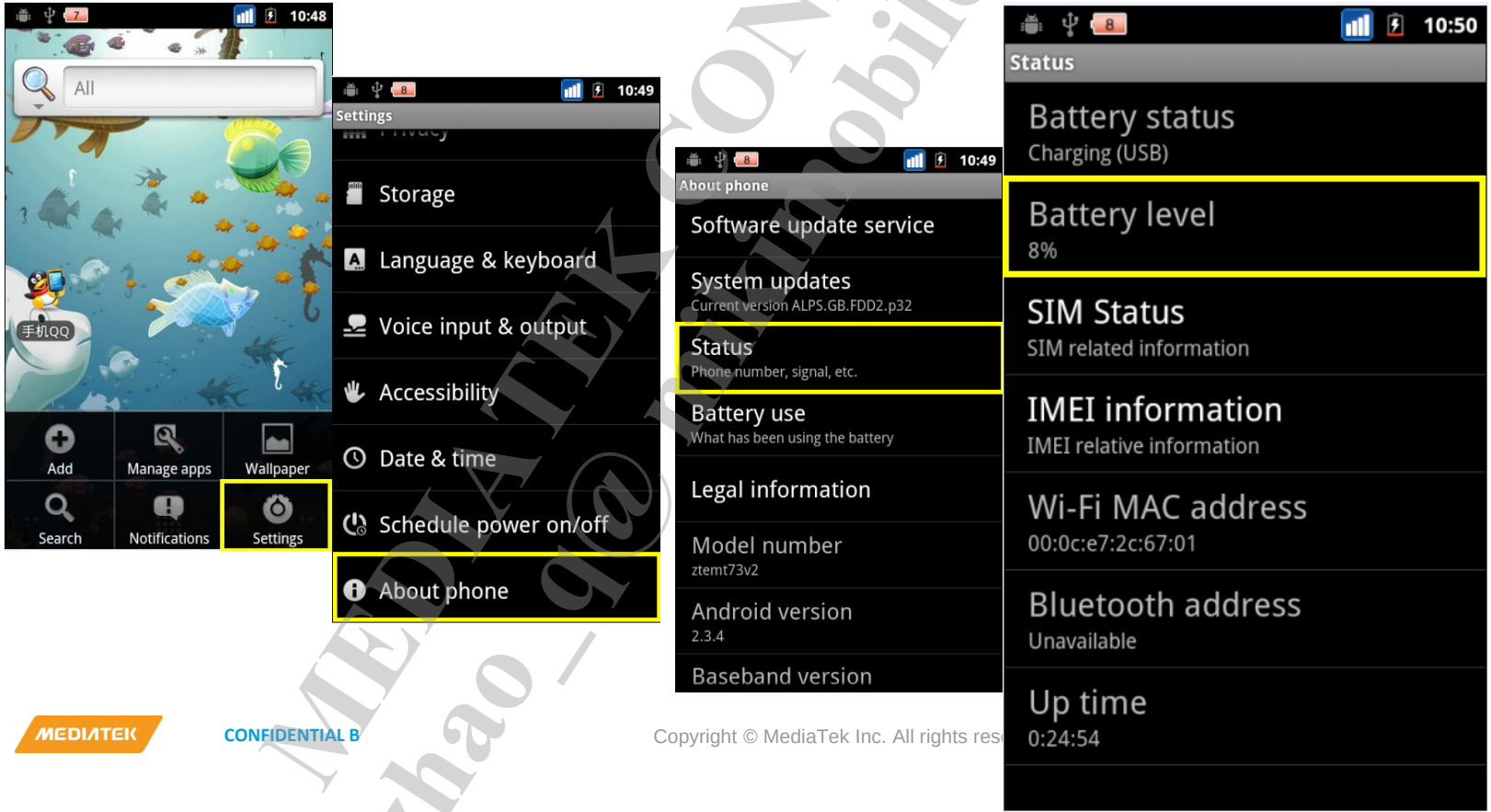
This is the real pcrcentage（A%）

Please follow the above instructions to look-up table and fill in the corresponding number，it will automatically calculate the battery percentage（A%）。

D0 precision test 3/4

Attention to the temperature 25℃

- Step 4： Put the battery inside the phone and power it on to show the battery percentage （B%）,then record the B%。
  - For example： the battery percentage is 8%（B%） shows below.
    - Show the Battery percentage ： Setting->About phone->Status->Battery level



D0 precision test 4/4

Attention to the temperature 25℃

- Step 5： D0 error=|A%-B%|<10%
  - D0 error=|A%-B%|=|99.10%-100%|=0.9% <10%
    - Note：The error is associated with the battery voltage measurement accuracy，so make sure the battery voltage is measuered accurately。
- Step 6： Discharge the battery to (95%,90%,85%,80%,75%,70%,65%,60%,25%,20%,15%, 10%)，repeat step 2 to step 6 until VBAT<3.5V 。Please record every D0 error value and confirm the correct.

Fuel Gauge ADC Current precision test

- Precondition: Have finished CAR_TUNE_VALUE correction and updated to load, then continue to the test。
- Step 1： Using the CAR_TUNE_VALUE adjustment environment (reference to page33), current setting 1000mA。
- Step 2： Press the power key to boot up the phone, Select the dial-up interface in the user interface， input password *#*#3646633#*#* to enter engineering mode then select Power->Charge Battery ,select the fifth row, FG_Battery_CurrentConsumption Ifg
- Step 3: Judge the current accuracy = (Iset-Ifg)/Iset less than± 3% or not。
  - Note：Iset， Ifg Fuel gauge engineering mode show。
- Step 4: Set current I from 200mA to1.5A（100mA step）, Repeat step 2 to 3。

SW Fuel gauge Application Notes

Agenda

- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Agenda

- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Design with Default ZCV table

Case of Customer Support		Customers	Pros	Cons	Effort
Use MTK Fuel Gauge	Use default ZCV Table	1. Need precise battery percentage 2. Can not get the battery ZCV table	1. Battery percentage error rate < 20% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)	Need Use default ZCV Table	NA
	MTK SA measure ZCV Table for each customer	**1.Need precise battery percentage 2. Can get the battery ZCV table**	**1. Battery percentage error rate <10% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)**	**Need 3 weeks for creating the ZCV table**	**Need provide the battery packet and SPEC to MTK SA for creating the ZCV table. (same as the flow of Gas Gauge IC vender)**

HW condition to enable Fuel gauge(must)

- Battery temperature detection circuit is a must
- –Note: Fuel gauge will monitor battery temperature and do algorithm compensation via temperature parameter, so battery temperature detection function is a must. NTC resistor value may choose 10Kohm@25℃ or 47Kohm@25 ℃, if another NTC resistor value is used, customer needs to built the NTC temperature table.

Customization file preparation

- The cust_fuel_gauge.h file needs to be modified for customization.

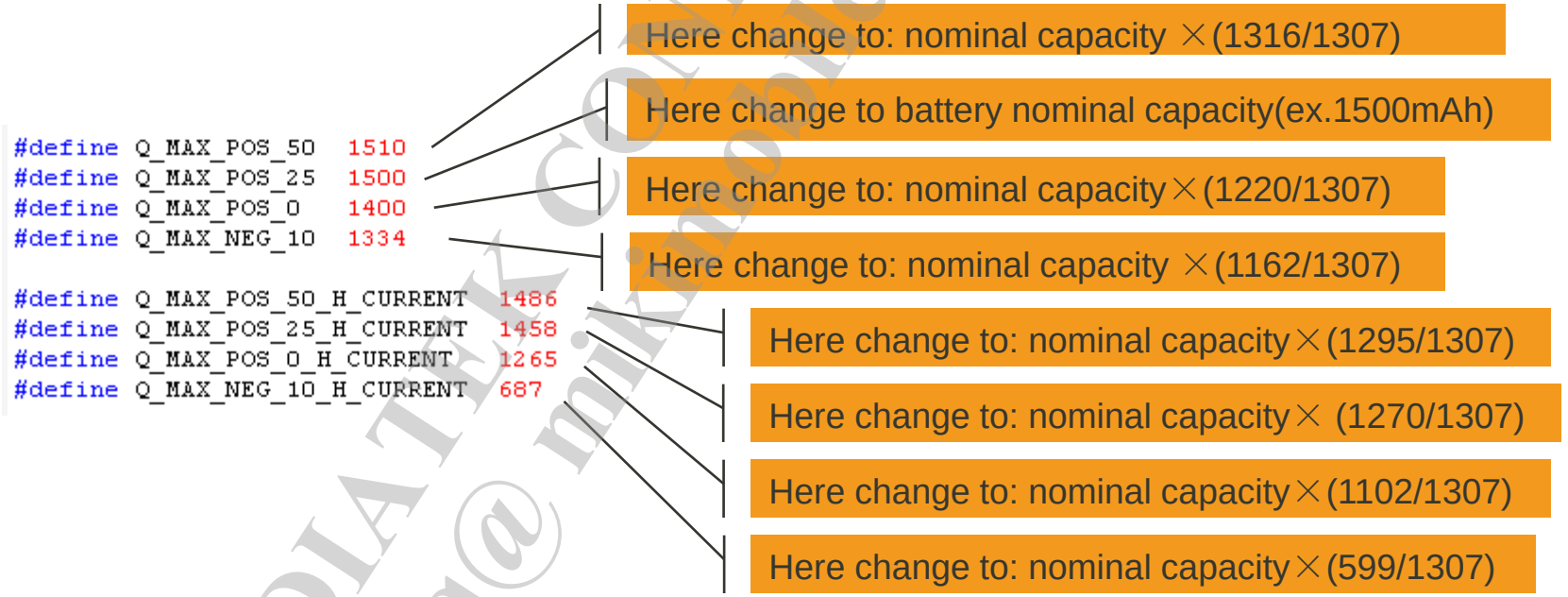
- Note： The default battery capacity is 1500mAh @MT6572， if you choose the battery capacity large different with 1500 mAh,you need to adjust the relative battery capacity parameter.
- Because customization is based on our default ZCV table, the deviation of battery gauge’s initial capacity will become a little big, but that will not influence Fuel gauge statistics deviation when using. And initial capacity deviation will auto calibration after a full charged or full discharged.

Customization of Battery Capacity

- Note: In addition to items need to be modified below, please don’t modify other parameter, or it may result in abnormity.

Q_MAX Replacement

- 1： Fill in the Q_MAX for 50℃、25 ℃、0 ℃、-10 ℃.
  - Noet:all data below take the integer portion.



Default ZCV Database

- 2： Because of using the Default ZCV Database， so you can use the related Database array without modification.

Fuel gauge Test

- After complete the modification aforementioned, you can test battery gauge for verification according to your own testing method. Since there is no test of ZCV table reference, battery test method is up to customers.
- Testing note:
  - 1: Fuel gauge only read battery temperature , battery voltage and Rfg current when booting, to calculate OCV(Open Circuit Voltage), then table look-up to get battery gauge percentage.
  - 2: After mobile boot up, Fuel gauge use Coulomb Counter to integrate over Rfg current, and get the battery capacity.
  - 3: For better user experience, our software have many tracking methods, tracking methods please refer The Fuel gauge Part in Design Notice . Avoid puzzling everybody.

Agenda

- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Design with Measure ZCV table

Case of Customer Support		Customers	Pros	Cons	
Use MTK Fuel Gauge	Use default ZCV Table	1. Need precise battery percentage 2. Can not get the battery ZCV table	1. Battery percentage error rate < 20% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)	Need Use default ZCV Table	
	MTK SA measure ZCV Table for each customer	**1.Need precise battery percentage 2. Can get the battery ZCV table**	**1. Battery percentage error rate <10% 2. Cost is cheaper than the Fuel Gauge IC (0.6~0.9US)**	**Need 3 weeks for creating the ZCV table**	**1. Need provide the battery packet and SPEC to MTK SA for creating the ZCV table. (same as the flow of Gas Gauge IC vender)**

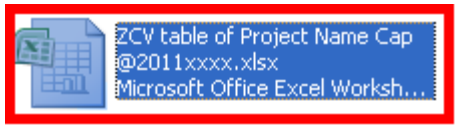
Fuel gauge battery ZCV table testing demand, please contact CPM

HW condition to enable Fuel gauge(must)

- Battery temperature detection circuit is a must
- –Note: Fuel gauge will monitor battery temperature and do algorithm compensation via temperature parameter, so battery temperature detection function is a must. NTC resistor value may choose 10Kohm@25 ℃ or 47Kohm@25 ℃, if another NTC resistor value is used, customer needs to built the NTC temperature table.

Fill in the material preparation

- Customer provide 3pcs bran-new original battery and battery datasheet for MTK testing, after testing, MTK will feedback ZCV table of XXXX @2012xxxx.xlsx file.
- The cust_battery_meter_table.h and cust_battery_meter.h file need to fill ZCV data.



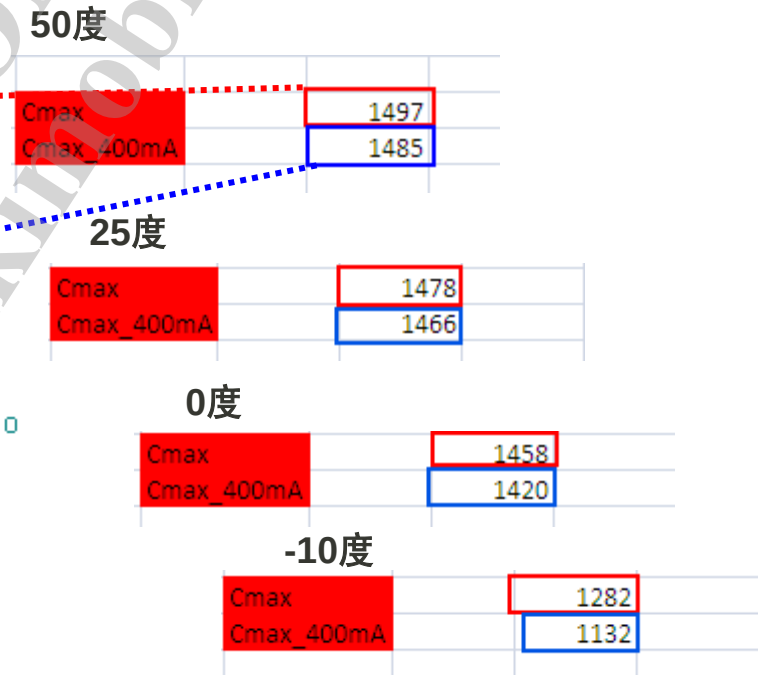
How to fill ZCV Data

- Note: In addition to items need to be modified below, please don’t modify other parameter, or it may result in abnormity.

Q_MAX Replacement

- 1： Use the Cmax\Cmax_400mA testing in 50℃、25℃、0℃、-10℃ to replace original corresponding temperature Q_MAX value respectively.
  - –Note: _H_CURRENT represent the battery discharging capacity in400mA condition.

```
89
90  #define Q_MAX_POS_50   1497
91  #define Q_MAX_POS_25   1478
92  #define Q_MAX_POS_0    1458
93  #define Q_MAX_NEG_10   1282
94
95  #define Q_MAX_POS_50_H_CURRENT   1485
96  #define Q_MAX_POS_25_H_CURRENT   1466
97  #define Q_MAX_POS_0_H_CURRENT    1420
98  #define Q_MAX_NEG_10_H_CURRENT   1132
99
100 #define R_FG_VALUE         20 // mOhm, base is 20
101 #define CURRENT_DETECT_R_FG 100  //10mA
```



OAM_D5 Replacement

- 2: Please change cust_battery_meter.h

  #define OAM_D5 1

  to

  #define OAM_D5 0

ZCV Database replace <DOD,OCV>

- 5-1： ZCV Database replacement， use the data in different temperature,50 ℃ ,25 ℃,0 ℃,-10 ℃,respectively, to replace original data.<DOD,OCV>

```
// <DOD, Battery_Voltage> Table
123  // T0 -10C
124  BATTERY_PROFILE_STRUC battery_profile_t0[] =
125  {
126    {0  , 4174},
127    {2  , 4158},
128    {5  , 4112},
129    {7  , 4074},
130    {9  , 4053},
131    {12 , 4038},
132    {14 , 4023},
133    {16 , 3998},
134    {19 , 3958},
135    {21 , 3941},
136    {23 , 3933},
137    {26 , 3922},
138    {28 , 3910},
139    {30 , 3897},
140    {33 , 3881},
141    {35 , 3867},
142    {37 , 3854},
143    {40 , 3842},
144    {42 , 3833},
145    {44 , 3824},
146    {47 , 3818},
147    {49 , 3812},
148    {51 , 3806},
149    {54 , 3801},
150    {56 , 3798},
151    {58 , 3793},
162    {84 , 3728},
163    {86 , 3721},
164    {88 , 3714},
165    {91 , 3709},
166    {93 , 3700},
167    {95 , 3674},
168    {98 , 3600},
169    {99 , 3550},
170    {99 , 3522},
171    {100, 3506},
172    {100, 3496},
173    {100, 3489},
174    {100, 3485},
175    {100, 3482},
176    {100, 3479},
177    {100, 3477},
178    {100, 3476},
179    {100, 3474},
180    {100, 3473},
181    {100, 3400},
182    {100, 3400},
183    {100, 3400},
184    {100, 3400}
185  };
186
```

負10度	OCV	VC	mAh	R(battery)	DOD	R(x1000)
	4174		0	0.34	0	340
	4158	4022	30	0.34	2	340
	4112	3976	60	0.34	5	340
	4074	3938	90	0.34	7	340
	4053	3918	119	0.3375	9	338
	4038	3899	149	0.3475	12	348
	4023	3875	179	0.37	14	370
	3998	383			16	413
	3958	372			19	578
	3941	367			21	678
	3933	3648	298	0.7125	23	713
	3922	3634	328	0.72	26	720
	3910	3621	358	0.7225	28	723
	3897	3607	388	0.725	30	725
	3881	3596	418	0.7125	33	713
	3867	3583	448	0.71	35	710
	3854	3573	478	0.7025	37	703
	3842	3563	507	0.6975	40	698
	3833	3554	537	0.6975	42	698
	3824	3545	567	0.6975	44	698
	3818	3537	597	0.7025	47	703
	3812	3530	627	0.705	49	705
	3806	3523	657	0.7075	51	708
	3801	3516	686	0.7125	54	713
	3798	3509	716	0.7225	56	723
	3793	3502	746	0.7275	58	728
	3791	3498	776	0.7325	61	733
	3788	3496	806	0.73	63	730

OCV： Open Circuit Voltage

DOD :Depth of Discharge

Note: the last pair data in the array haven't "," symbol, comma symbol.

ZCV Database replace <DOD,OCV>

- 5-2： if data length in ZCV table isn't equal to array length in code. Just adjust the array length in SW code, let it equal the data length in ZCV table. Exp:184-125=60-1=59, so adjust all array length to 59, including {0,0} array.

```
123  // T0 -10C
124  BATTERY_PROFILE_STRUC battery_profile_t0[] =
125  {
126      {0  , 4174},
127      {2  , 4158},
128      {5  , 4112},
129      {7  , 4074},
130      {9  , 4053},
131      {12 , 4038},
132      {14 , 4023},
133      {16 , 3998},
134      {19 , 3958},
135      {21 , 3941},
```

```
178      {100, 3476},
179      {100, 3474},
180      {100, 3473},
181      {100, 3400},
182      {100, 3400},
183      {100, 3400},
184      {100, 3400}
185  };
186
187  // T1 OC
```

1	負10度	OCV	VC	mAh	R(battery)	DOD	R(x1000)
2		4174		0	0.34	0	340
3		4158	4022	30	0.34	2	340
4		4112	3976	60	0.34	5	340
5		4074	3938	90	0.34	7	340
6		4053	3918	119	0.3375	9	338
7		4038	3899	149	0.3475	12	348
8		4023	3875	179	0.37	14	370
9		3998	3833	209	0.4125	16	413
10		3958	3727	239	0.5775	19	578

52		3479	3198	1281	0.7025	100	703
53		3477	3197	1281	0.7	100	700
54		3476	3199	1281	0.6925	100	693
55		3474	3195	1282	0.6975	100	698
56		3473	3196	1282	0.6925	100	693
57		3400	3193	1282	0.5175	100	518
58		3400	3193	1282	0.5175	100	518
59		3400	3193	1282	0.5175	100	518
60		3400	3193	1282	0.5175	100	518
61							
62							

ZCV Database replace <Rbat,OCV>

- 6:ZCV Database replacement, use the data in different temperature, 50℃, 25℃, 0℃, -10℃, respectively, to replace original data. <Rbat, OCV> , the method is the same as <DOD,OCV>, attention equal length of the array.

```
////////////////////////////////////////
// <Rbat, Battery_Voltage> Table
////////////////////////////////////////
// T0 -10C
R_PROFILE_STRUC r_profile_t0[] =
{
    {340, 4174},
    {340, 4158},
    {340, 4112},
    {340, 4074},
    {338, 4053},
    {348, 4038},
    {370, 4023},
    {413, 3998},
    {578, 3958},
    {678, 3941},
    {713, 3933},
    {720, 3922},
    {723, 3910},
    {725, 3897},
    {713, 3881},
    {710, 3867},
    {703, 3854},
    {770, 3506},
    {745, 3496},
    {728, 3489},
    {718, 3485},
    {710, 3482},
    {703, 3479},
    {700, 3477},
    {693, 3476},
    {698, 3474},
    {693, 3473},
    {518, 3400},
    {518, 3400},
    {518, 3400},
    {518, 3400}
};
```

Note: the last pair data in the array haven't "," symbol, comma symbol.

負10度	OCV	VC	mAh	R(battery)	DOD	R(x1000)
	4174		0	0.34	0	340
	4158	4022	30	0.34	2	340
	4112	3976	60	0.34	5	340
	4074	3938	90	0.34	7	340
	4053	3918	119	0.3375	9	338
	4038	3899	149	0.3475	12	348
	4023	3875	179	0.37	14	370
	3998	3833	209	0.4125	16	413
	3958	3727	239	0.5775	19	578
	3941	3670	269	0.6775	21	678
	3933	3648	298	0.7125	23	713
	3922	3634	328	0.72	26	720
	3910	3621	358	0.7225	28	723
	3897	3607	388	0.725	30	725
	3881	3596	418	0.7125	33	713
	3867	3583	448	0.71	35	710
	3854	3573	478	0.7025	37	703
	3842	3563	507	0.6975	40	698
	3833	3554	537	0.6975	42	698
	3824	3545	567	0.6975	44	698
	3818	3537	597	0.7025	47	703
	3812	3530	627	0.705	49	705

Fuel gauge Test

- After complete the modification aforementioned, you can test battery gauge for verification according to Fuel Gauge Test Way Introduction. You can also do the verification using your own testing method.
- Testing note:
  - 1: Fuel gauge only read battery temperature , battery voltage and Rfg current when booting, to calculate OCV(Open Circuit Voltage), then table look-up to get battery gauge percentage.
  - 2: After mobile boot up, Fuel gauge use Coulomb Counter to integrate over Rfg current, and get the battery capacity.
  - 3: For better user experience, our software have many tracking methods, tracking methods please refer The Fuel gauge Part in Design Notice . Avoid puzzling everybody.

Agenda

- Design with Default ZCV table
- Design with Measure ZCV table
- Fuel Gauge Test Way Introduction

Agenda

- Test equipment requirements
- D0 precision test
- Charge/Discharge Fuel gauge percentage precision test

Test equipment requirements

- High precision Voltmeter
  - Accurately measuring the battery voltage, Accuracy is more than ±0.1mV。
  - Example： Keithley 2700
    - Note： The accuracy of the voltage measurement affects the accuracy of the test。

Bad

Good

D0 precision test 1/4

Attention to the temperature 25℃

- Step 1： Put the battery in the phone and have it full charged，then take it out.
  - Note： Gauge show100%， then take out the battery.（Please take out the battery in 10 mins after full charged）
    - Show battery percent： Settings->About phone->Status->Battery level
- Step 2： Take out the battery and make it stay in inactive state for 30 mins， measure the battery voltage and record $V_{battery}$.
  - For example： $V_{Battery}$ =4.17644V

D0 precision test 2/4

Attention to the temperature 25℃

- Step 3： Accordding to $V_{battery,}$Look up the ZCV curve and find the percentage D_ZCV(Look-up table method),get the actual battery percentage（A%）and record it.
  - $V_{Battery}$=4.17644V,using the look-up table method to get the actual percentage.
    - 4.17644V is between 4.188V and 4.175V， We can calculate the real percentage in MTK provided ZCV table is 99.10125%（A%）.Attention to the normal temperature,please refer to 25℃ ZCV table.

25度	OCV	VC	mAh	R(battery)	DOD
	4188		0		0
	4175	4113	20	0.155	1
	4162	4100	40	0.155	3
	4147	4086	60	0.1525	4
	4134	4074	80	0.15	5
	4122	4062	100	0.15	7
	4111	4050	120	0.1525	8
	4099	4038	140	0.1525	9

常溫驗證	x1(max)	x2(min)	y1(DOD)	y2(DOD)	y(result)
	4188	4175	0	1	0.889231
					99.11077
				指示百分	99.10125
			30分钟之	4.17644	

This is the real pcrcentage（A%）

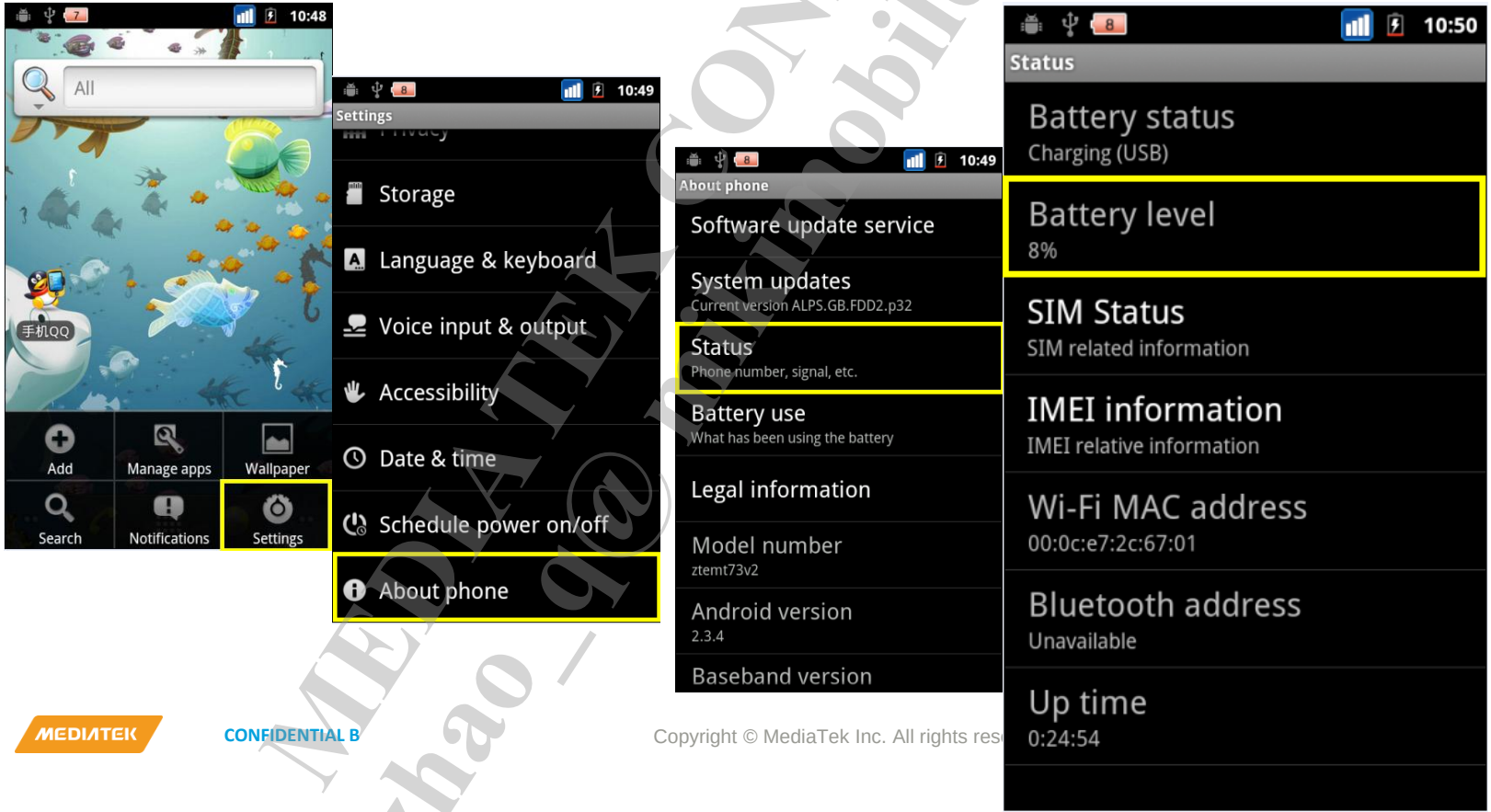
注意：常溫下測試，查表請參考25度時量測的ZCV表

Please follow the above instructions to look-up table and fill in the corresponding number，it will automatically calculate the battery percentage（A%）。

D0 precision test 3/4

Attention to the temperature 25℃

- Step 4： Put the battery inside the phone and power it on to show the battery percentage （B%）,then record the B%。
  - For example： the battery percentage is 8%（B%） shows below.
    - Show the Battery percentage ： Setting->About phone->Status->Battery level



D0 precision test 4/4

Attention to the temperature 25℃

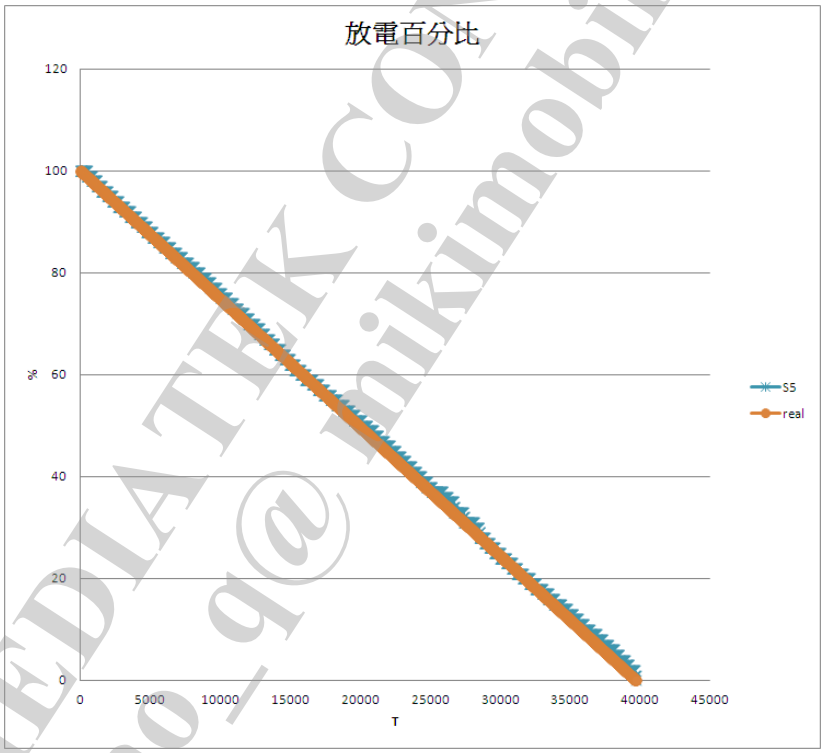
- Step 5： D0 error=|A%-B%|<10%
  - D0 error=|A%-B%|=|99.10%-100%|=0.9% <10%
    - Note：The error is associated with the battery voltage measurement accuracy，so make sure the battery voltage is measuered accurately。
- Step 6： Discharge the battery to (95%,90%,85%,80%,75%,70%,65%,60%,25%,20%,15%, 10%)，repeat step 2 to step 6 until VBAT<3.5V 。Please record every D0 error value and confirm the correct.

Discharge Fuel gauge percentage precision test

- Step 1: Connect UART to receive FG Log
- Step 2: Put the battery in the phone and have it full charged
- Step 3: Run stress load app (Keep the screen will not shut down),until the phone automatically shut down.
  - The test condition can be changed, but the test (100%~0%Overloading or Mediumloading or Lowloading) loading should be consistent.
- Step 4: Get the FG log and arrange information,
  - [11779.032482] (1) [47:bat_thread_kthr][Power/BatMeter] [oam_result_inf] 1, 1, 1, 1, 1, 99
  - 11779.032482 time information, 1, 1, 1, 1, 1(72 FG original percentage), 99 (72 UI SOC percentage)

Discharge Fuel gauge percentage precision test

- Step 4: Use the Log information to describe curve in Excel
  - Idear curve is a line between100% and 0%, the bias between Ideal curve and test curve is FG error,also the error needs to be less than 10% (If the error is more than 10%,please make sure the customization parameters Qmax)

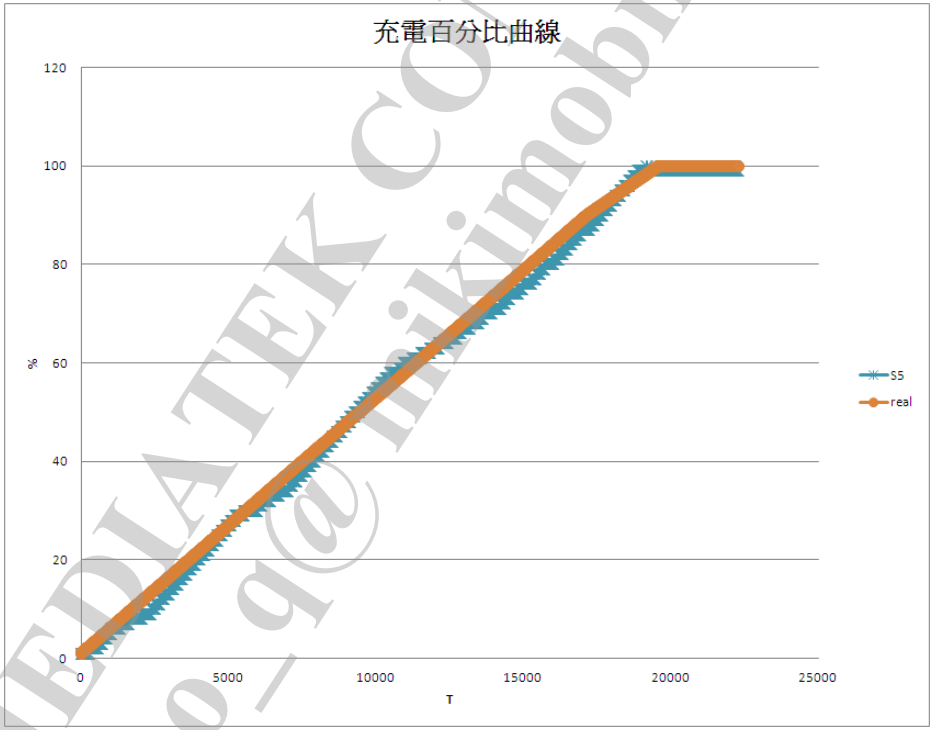


Charge Fuel gauge percentage precision test

- Step 1: Connect UART to receive FG Log
- Step 2: Use the mobile phone until automatic shutdown
- Step 3: Connect Charger (AC or USB) and wait for the successful start up
- Step 4: Press the PWRKEY to shutdown the screen and charge the battery to100%
  - The test condition (100%~0% AC charger or USB charger) charge current should be consistent
- Step 5: : Get the FG log and arrange information
  - [11779.032482] (1) [47:bat_thread_kthr][Power/BatMeter] [oam_result_inf] 1, 1, 1, 1, 1, 99
  - 11779.032482 time information, 100, 100, 100, 100, 100(72 FG original percentage), 1 (72 UI SOC percentage)

Charge Fuel gauge percentage precision test

- Step 6: Use the Log information to describe curve in Excel
  - Idear curve is a line between 90% and 0%, the bias between Ideal curve and test curve is FG error,also the error needs to be less than 10% (If the error is more than 10%,please make sure the customization parameters Qmax)



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