The Output Current Sensing based on UCD9224E and UCD74120

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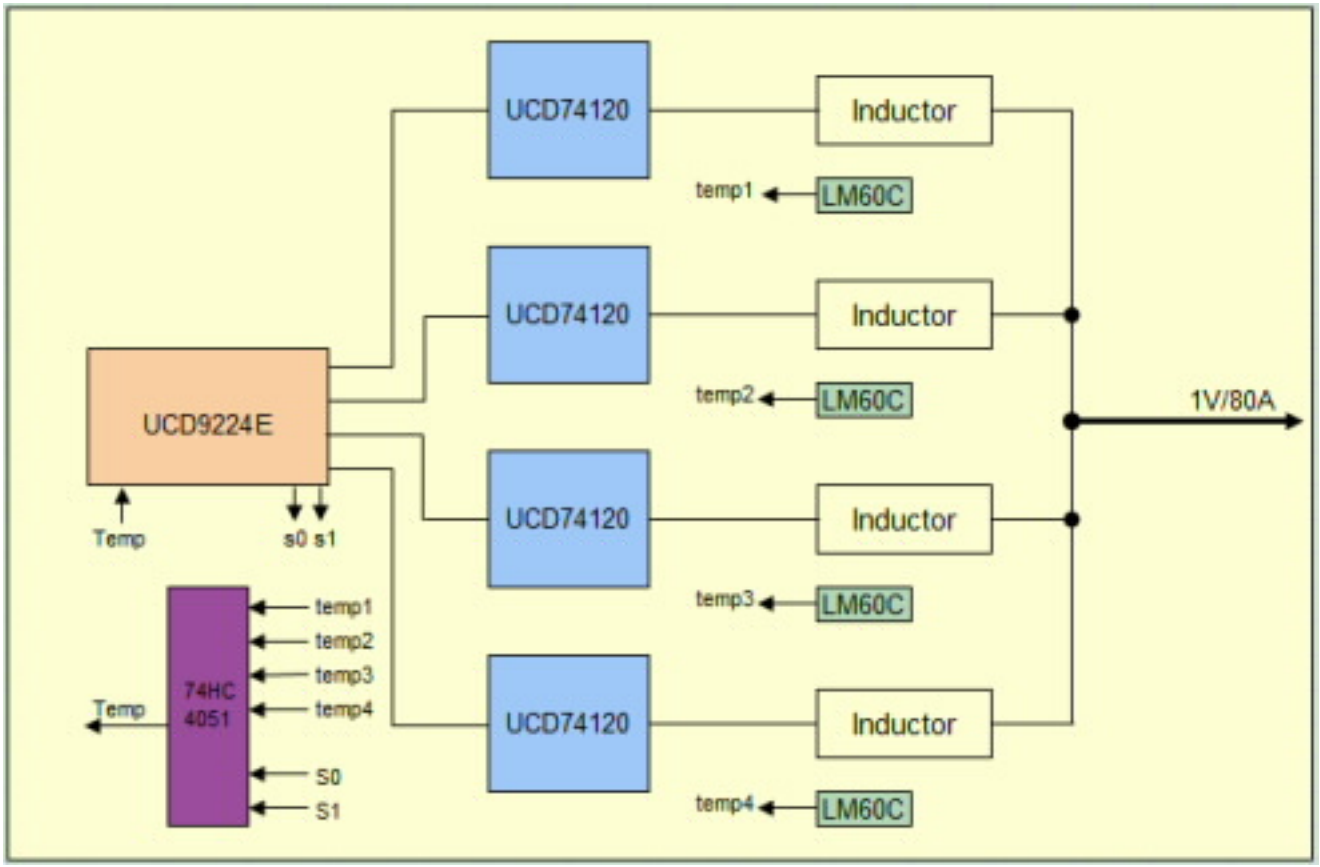
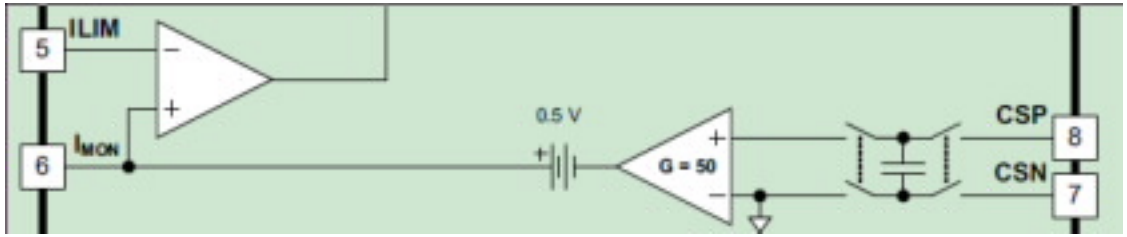
Block Diagram and Spec.

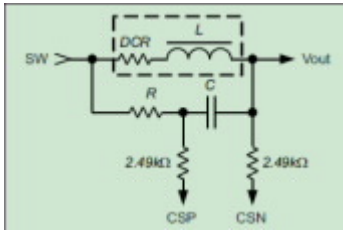
This non-isolated digital power is based on digital controller UCD9224E.
There are 4 phases in parallel, and the power stage uses UCD74120;
The input voltage of this power is 12V and the output is 1V/80A.

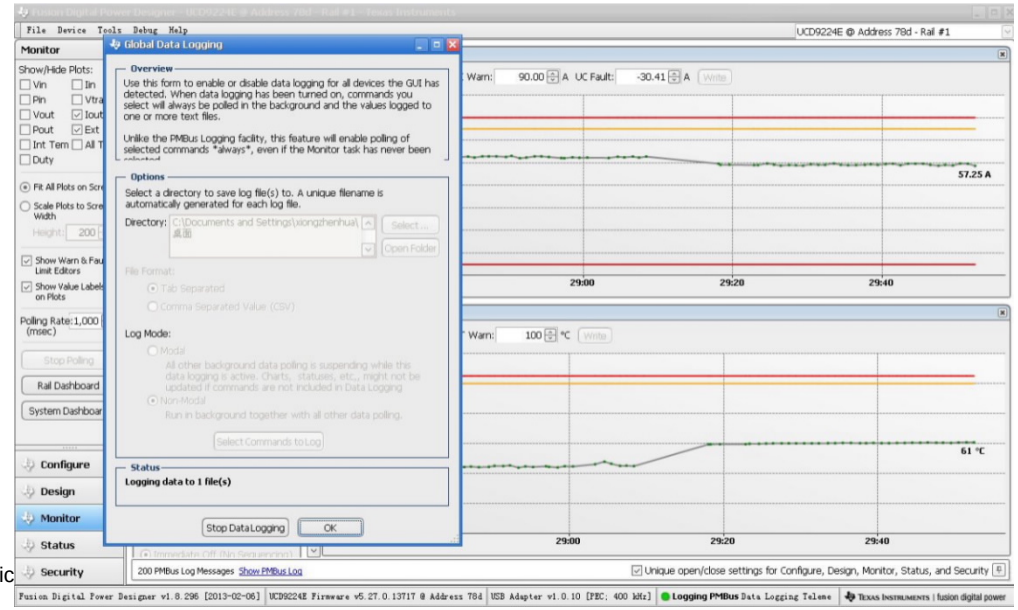


Output current sensing

- Sense the voltage on DCR of output inductor by UCD74120;
- Amplify this voltage and add offset, then output voltage by UCD74120;
- Sense the voltage at UCD74120's I_{MON} pin by UCD9224E;
- UCD9224E firmware calculates the value of output current, and shows it on the GUI







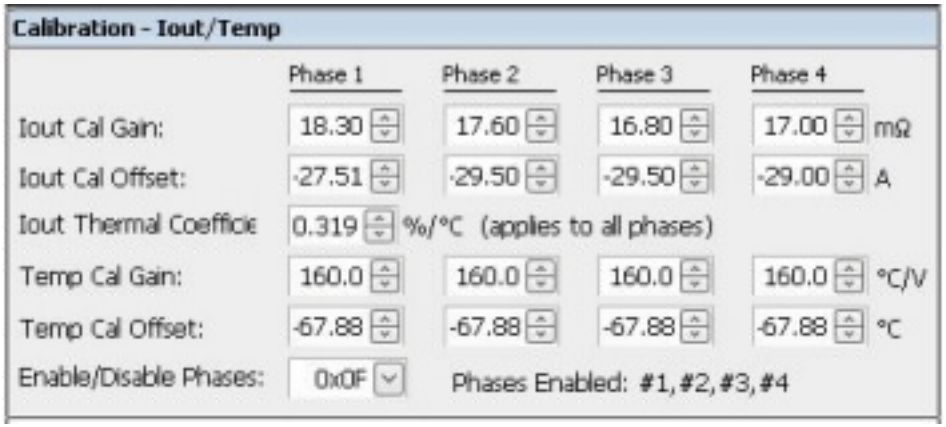
Temperature compensation for DCR

As all know, DCR changes when the ambient temperature of inductor varies, which causes the value of output current on GUI deviates the real value.

UCD9224E firmware owns the function of temperature compensation for DCR. After acquiring the temperature of inductor, firmware can calculate the current DCR value, then calibrate the output current value on GUI.

To realize this function, only needs user to do the next:

1. add a temperature sensor, which should be closed to inductor;
2. Configure coefficient about the temperature sensor on GUI;
   - Iout Cal Gain/Iout Cal Offset: records the gain and offset of the voltage on DCR
   - Iout Thermal coefficient: temperature coefficient of resistance
   - Temp Cal Gain/Temp Cal Offset: the relations of sensor's output and temperature.



Test results:

Conditions:

- In lab, there is no fan on the board, and the ambient temperature is 25C;
- After the board running for a while, the core temperature of inductor increases, so we have to enable temperature compensation function.

Datum gather:

Keep the output current stable, gather the value on the GUI. For every value, read 20 times and then average them.

Measurement datum:

In the range of 10A to 80A, the error is less than 5%.

Real value/A	5	10	15	20	25	30	40	50	60	70	80
Value on GUI/A	5.78	10.57	15.22	20.26	24.99	29.58	39.15	48.94	58.11	68.06	77.66
error	15.66%	5.70%	1.50%	1.30%	0.00%	1.40%	2.10%	2.10%	3.20%	2.80%	2.90%
Remark		In the range of 10A to 80A, error <5%									

Test results without temp compensation:

Measurement datum:

Powering on the board and running for about 3mintues, without temperature compensation. Keep the output current to be 60A, the value on the GUI is 64.41A. So, the error is more than 7.35%.

	with temp comp	without temp comp
Real value/A	60	60
Value on GUI/A	58.11	64.41
error	3.20%	7.35%

If the board running in high ambient, such as 70℃, the accuracy will be worse because the DCR changes suddenly.

Conclusion:

Using the DCR approach to sense output current, with temperature compensation function, can realize high accuracy in medium load and heave load.

Based on the board mentioned before, test results show that measuring error is less than 5% from 10A to 80A.

Remark: measurement datum (1)
--with temperature compensation

The output current is 10A. The error is 5.73%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
13:56:30	UCD9224E	78	10.3438	10.57	10	0.0573
13:56:31	UCD9224E	78	10.6406			
13:56:32	UCD9224E	78	10.5781			
13:56:33	UCD9224E	78	10.2031			
13:56:34	UCD9224E	78	10.1875			
13:56:35	UCD9224E	78	11			
13:56:36	UCD9224E	78	10.7188			
13:56:37	UCD9224E	78	10.5313			
13:56:38	UCD9224E	78	10.1094			
13:56:39	UCD9224E	78	10.625			
13:56:40	UCD9224E	78	10.0938			
13:56:41	UCD9224E	78	10.5			
13:56:42	UCD9224E	78	11.4375			
13:56:43	UCD9224E	78	10.9688			
13:56:44	UCD9224E	78	10.4219			
13:56:45	UCD9224E	78	10.8281			
13:56:46	UCD9224E	78	10.4063			
13:56:47	UCD9224E	78	9.8594			
13:56:48	UCD9224E	78	11.0313			
13:56:49	UCD9224E	78	10.9844			

Remark: measurement datum (2)
--with temperature compensation

The output current is 15A. The error is 1.47%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
13:58:55	UCD9224E	78	15.4219	15.22	15	0.0147
13:58:56	UCD9224E	78	15.0625			
13:58:57	UCD9224E	78	14.7813			
13:58:58	UCD9224E	78	14.7188			
13:58:59	UCD9224E	78	15.5938			
13:59:00	UCD9224E	78	14.4844			
13:59:01	UCD9224E	78	15.2188			
13:59:02	UCD9224E	78	16.1875			
13:59:03	UCD9224E	78	15.4375			
13:59:04	UCD9224E	78	16.0938			
13:59:05	UCD9224E	78	14.7813			
13:59:06	UCD9224E	78	14.4375			
13:59:07	UCD9224E	78	15.5469			
13:59:08	UCD9224E	78	15.1094			
13:59:09	UCD9224E	78	15.375			
13:59:10	UCD9224E	78	15.4844			
13:59:11	UCD9224E	78	14.8281			
13:59:12	UCD9224E	78	15.7969			
13:59:13	UCD9224E	78	14.7188			
13:59:14	UCD9224E	78	15.3438			

Remark: measurement datum (3)
--with temperature compensation

The output current is 20A. The error is 1.31%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:00:44	UCD9224E	78	19.9063	20.26	20	0.0131
14:00:45	UCD9224E	78	20.375			
14:00:46	UCD9224E	78	19.3125			
14:00:47	UCD9224E	78	20.7813			
14:00:48	UCD9224E	78	19.75			
14:00:49	UCD9224E	78	20.3125			
14:00:50	UCD9224E	78	19.5625			
14:00:51	UCD9224E	78	21.125			
14:00:52	UCD9224E	78	18.3438			
14:00:53	UCD9224E	78	21.375			
14:00:54	UCD9224E	78	21.5			
14:00:55	UCD9224E	78	20.0313			
14:00:56	UCD9224E	78	19.6563			
14:00:57	UCD9224E	78	21.3125			
14:00:58	UCD9224E	78	19.125			
14:00:59	UCD9224E	78	19.2813			
14:01:00	UCD9224E	78	20.25			
14:01:01	UCD9224E	78	20.6563			
14:01:02	UCD9224E	78	21			
14:01:03	UCD9224E	78	21.5938			

Remark: measurement datum (4)
--with temperature compensation

The output current is 25A. The error is 0.4%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:02:35	UCD9224E	78	24.5938	24.99	25	-0.0004
14:02:36	UCD9224E	78	25.2813			
14:02:37	UCD9224E	78	24.5313			
14:02:38	UCD9224E	78	23.875			
14:02:39	UCD9224E	78	24.25			
14:02:40	UCD9224E	78	25.75			
14:02:41	UCD9224E	78	24.9688			
14:02:42	UCD9224E	78	25.2813			
14:02:43	UCD9224E	78	24.0313			
14:02:44	UCD9224E	78	25.9063			
14:02:45	UCD9224E	78	25.75			
14:02:46	UCD9224E	78	25.625			
14:02:47	UCD9224E	78	24.3438			
14:02:48	UCD9224E	78	23.6563			
14:02:49	UCD9224E	78	25.5313			
14:02:50	UCD9224E	78	23.9063			
14:02:51	UCD9224E	78	25.9063			
14:02:52	UCD9224E	78	26			
14:02:53	UCD9224E	78	25.6875			
14:02:54	UCD9224E	78	24.9063			

Remark: measurement datum (5)
--with temperature compensation

The output current is 30A. The error is 1.42%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:04:20	UCD9224E	78	29.125	29.58	30	0.0142
14:04:21	UCD9224E	78	29.5625			
14:04:22	UCD9224E	78	30.2188			
14:04:23	UCD9224E	78	29.9063			
14:04:24	UCD9224E	78	29.4375			
14:04:25	UCD9224E	78	29.8125			
14:04:26	UCD9224E	78	29.375			
14:04:27	UCD9224E	78	29.6875			
14:04:28	UCD9224E	78	28.875			
14:04:29	UCD9224E	78	30.0938			
14:04:30	UCD9224E	78	29.5938			
14:04:31	UCD9224E	78	29.5625			
14:04:32	UCD9224E	78	29.9688			
14:04:33	UCD9224E	78	29.8438			
14:04:34	UCD9224E	78	29.1563			
14:04:35	UCD9224E	78	30.125			
14:04:36	UCD9224E	78	29.2188			
14:04:37	UCD9224E	78	29.9688			
14:04:38	UCD9224E	78	29.0313			
14:04:39	UCD9224E	78	28.9375			

Remark: measurement datum (6)
--with temperature compensation

The output current is 40A. The error is 2.13%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:06:35	UCD9224E	78	39.5	39.15	40	-0.0213
14:06:36	UCD9224E	78	39			
14:06:37	UCD9224E	78	38.1875			
14:06:38	UCD9224E	78	39.5			
14:06:39	UCD9224E	78	39.125			
14:06:40	UCD9224E	78	39.125			
14:06:41	UCD9224E	78	38.5			
14:06:42	UCD9224E	78	39.3125			
14:06:43	UCD9224E	78	39.3125			
14:06:44	UCD9224E	78	39.5			
14:06:45	UCD9224E	78	39.3125			
14:06:46	UCD9224E	78	39.8125			
14:06:47	UCD9224E	78	39.8125			
14:06:48	UCD9224E	78	38.6875			
14:06:49	UCD9224E	78	39.625			
14:06:50	UCD9224E	78	38.875			
14:06:51	UCD9224E	78	38.125			
14:06:52	UCD9224E	78	39.25			
14:06:53	UCD9224E	78	38.625			
14:06:54	UCD9224E	78	39.75			

Remark: measurement datum (7)
--with temperature compensation

The output current is 50A. The error is 2.11%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:09:05	UCD9224E	78	49.5	48.94	50	0.0211
14:09:06	UCD9224E	78	49.75			
14:09:07	UCD9224E	78	48.375			
14:09:08	UCD9224E	78	49.0625			
14:09:09	UCD9224E	78	49.25			
14:09:10	UCD9224E	78	49.875			
14:09:11	UCD9224E	78	48.875			
14:09:12	UCD9224E	78	49.5			
14:09:13	UCD9224E	78	49.0625			
14:09:14	UCD9224E	78	49.0625			
14:09:15	UCD9224E	78	48.625			
14:09:16	UCD9224E	78	49.125			
14:09:17	UCD9224E	78	47.3125			
14:09:18	UCD9224E	78	48.625			
14:09:19	UCD9224E	78	49.125			
14:09:20	UCD9224E	78	48			
14:09:21	UCD9224E	78	48.25			
14:09:22	UCD9224E	78	49.625			
14:09:23	UCD9224E	78	48.6875			
14:09:24	UCD9224E	78	49.1875			

Remark: measurement datum (8)
--with temperature compensation

The output current is 60A. The error is 3.15%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:10:45	UCD9224E	78	57.875	58.11	60	0.0315
14:10:46	UCD9224E	78	58.25			
14:10:47	UCD9224E	78	58.125			
14:10:48	UCD9224E	78	56.875			
14:10:49	UCD9224E	78	57.8125			
14:10:50	UCD9224E	78	57.8125			
14:10:51	UCD9224E	78	58.3125			
14:10:52	UCD9224E	78	57.625			
14:10:53	UCD9224E	78	58.8125			
14:10:54	UCD9224E	78	58.625			
14:10:55	UCD9224E	78	57.75			
14:10:56	UCD9224E	78	58.75			
14:10:57	UCD9224E	78	58.125			
14:10:58	UCD9224E	78	57.5625			
14:10:59	UCD9224E	78	58.5			
14:11:00	UCD9224E	78	58.6875			
14:11:01	UCD9224E	78	58.125			
14:11:02	UCD9224E	78	57.3125			
14:11:03	UCD9224E	78	58.875			
14:11:04	UCD9224E	78	58.375			

Remark: measurement datum (9)
--with temperature compensation

The output current is 70A. The error is 2.77%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:12:40	UCD9224E	78	67.25	68.06	70	0.0277
14:12:41	UCD9224E	78	67.75			
14:12:42	UCD9224E	78	68			
14:12:43	UCD9224E	78	69.375			
14:12:44	UCD9224E	78	68.375			
14:12:45	UCD9224E	78	68			
14:12:46	UCD9224E	78	68.125			
14:12:47	UCD9224E	78	68.125			
14:12:48	UCD9224E	78	68.375			
14:12:49	UCD9224E	78	67.875			
14:12:50	UCD9224E	78	68.125			
14:12:51	UCD9224E	78	68.5			
14:12:52	UCD9224E	78	68			
14:12:53	UCD9224E	78	67.5			
14:12:54	UCD9224E	78	68.625			
14:12:55	UCD9224E	78	68.875			
14:12:56	UCD9224E	78	67.75			
14:12:57	UCD9224E	78	66.625			
14:12:58	UCD9224E	78	68.125			
14:12:59	UCD9224E	78	67.875			

Remark: measurement datum (10)
--with temperature compensation

The output current is 80A. The error is 2.92%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:14:20	UCD9224E	78	77.625	77.66	80	0.0292
14:14:21	UCD9224E	78	77			
14:14:22	UCD9224E	78	77.375			
14:14:23	UCD9224E	78	77.125			
14:14:24	UCD9224E	78	77.875			
14:14:25	UCD9224E	78	78.125			
14:14:26	UCD9224E	78	77.5			
14:14:27	UCD9224E	78	78.125			
14:14:28	UCD9224E	78	78.375			
14:14:29	UCD9224E	78	78.125			
14:14:30	UCD9224E	78	77.625			
14:14:31	UCD9224E	78	77.875			
14:14:32	UCD9224E	78	76.625			
14:14:33	UCD9224E	78	77.75			
14:14:34	UCD9224E	78	77.75			
14:14:35	UCD9224E	78	76.75			
14:14:36	UCD9224E	78	77.75			
14:14:37	UCD9224E	78	78.25			
14:14:38	UCD9224E	78	78.375			
14:14:39	UCD9224E	78	77.25			

Remark: measurement datum (11)
--with temperature compensation

The output current is 5A. The error is 15.64%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Error
14:19:44	UCD9224E	78	5.3125	5.78	5	0.1564
14:19:45	UCD9224E	78	6.5625			
14:19:47	UCD9224E	78	5.7031			
14:19:47	UCD9224E	78	6.9063			
14:19:48	UCD9224E	78	5.2188			
14:19:49	UCD9224E	78	5.1875			
14:19:50	UCD9224E	78	5.0938			
14:19:51	UCD9224E	78	5.7656			
14:19:52	UCD9224E	78	6.375			
14:19:53	UCD9224E	78	6.2188			
14:19:54	UCD9224E	78	5.5313			
14:19:55	UCD9224E	78	5.9531			
14:19:56	UCD9224E	78	6.6563			
14:19:57	UCD9224E	78	5.7031			
14:19:58	UCD9224E	78	5.8594			
14:19:59	UCD9224E	78	5.2344			
14:20:00	UCD9224E	78	4.9375			
14:20:02	UCD9224E	78	6.0313			
14:20:03	UCD9224E	78	5.1563			
14:20:03	UCD9224E	78	6.2344			

Remark: measurement datum (11)

--without temperature compensation

The output current is 60A (running for 3 mintues). The error is 7%

Timestamp	Part_ID	Address	READ_IOUT_1	Average Value	Real IOUT	Accuracy
41375.60	UCD9224E	78	65	64.409375	60	0.07
41375.60	UCD9224E	78	64.375			
41375.60	UCD9224E	78	63.5625			
41375.60	UCD9224E	78	64.375			
41375.60	UCD9224E	78	65			
41375.60	UCD9224E	78	64.625			
41375.60	UCD9224E	78	64.375			
41375.60	UCD9224E	78	63.875			
41375.60	UCD9224E	78	63.8125			
41375.60	UCD9224E	78	64.625			
41375.60	UCD9224E	78	64.875			
41375.60	UCD9224E	78	64.5			
41375.60	UCD9224E	78	64.25			
41375.60	UCD9224E	78	63.9375			
41375.60	UCD9224E	78	64.125			
41375.60	UCD9224E	78	64.75			
41375.60	UCD9224E	78	64.5			
41375.60	UCD9224E	78	64.5			
41375.60	UCD9224E	78	64			
41375.60	UCD9224E	78	65.125			

Thanks!