Reflow and PCB Assembly Effects on Renesas FGA References

Introduction

The Renesas floating gate analog (FGA) technology utilizes a robust stored charge technology borrowed from a standard EEPROM process to produce a precise reference voltage. The stored voltage is the heart of a highly accurate precision voltage reference product. The resulting voltage reference has excellent characteristics; very low temperature drift (3ppm/°C), high initial accuracy, and extremely low supply current (<1µA). The reference voltage is not limited to “magic” voltages obtained from bandgap references or buried Zener diodes to achieve temperature drift cancellation.

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1. Background

The floating gate storage cell requires two tunnel diodes to inject charge into a storage capacitor, see Figure 1. The tunnel diodes require high voltage, >10V, to turn on and when unbiased have extremely high impedance and essentially zero charge leakage.

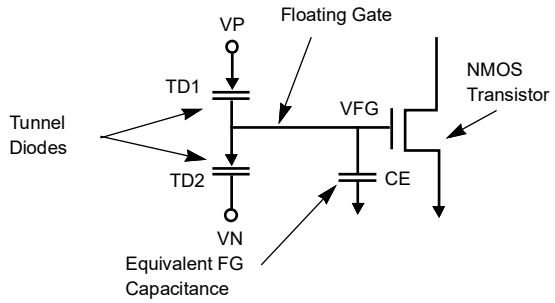


Figure 1. Floating Gate Cell

The actual voltage reference circuit contains two of the floating gate capacitors and an op amp see Figure 2. One capacitor sets the common-mode voltage and the other sets the output reference voltage. The switches shown in Figure 2 are the tunnel diodes and the VCM and V_{REF} shown are external voltages applied to program the cell at factory test. The output reference voltage is the difference between the common-mode and reference capacitors, allowing output voltage flexibility and adding temperature compensation.

The resulting circuit is highly stable, and the supply current is entirely dependent on the op amp, with extremely low current (<1µA) for low-power or higher-current for low-noise applications.

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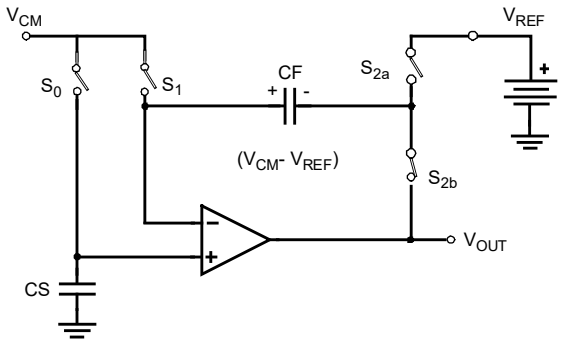


Figure 2. Floating Gate Reference Circuit Shown in Stable V_{OUT} State

2. Thermal Considerations

FGA references have thermal hysteresis, similar to bandgap or other reference technologies. As the packaged device goes through a temperature cycle, the package and die permanently change shape, very slightly, but enough to affect the electrical properties. Multiple cycles result in different shifts, and after a few cycles the overall change from the initial voltage stabilizes. The datasheet provides a thermal hysteresis specification for temperature excursions within the absolute maximum temperature range. Figure 3 shows the typical thermal hysteresis of FGA product with 50ppm drift over the specified range (-40°C to +125°C). There is no maximum specified because the device cannot be tested over multiple cycles at the factory.

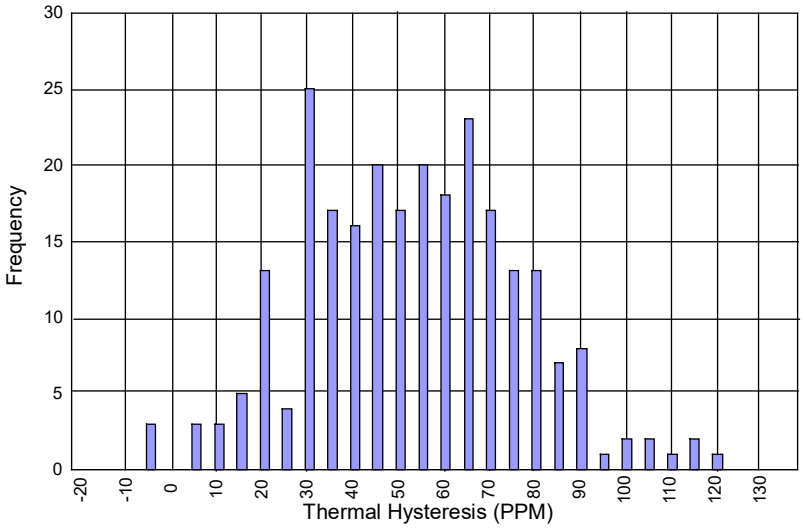


Figure 3. Typical Thermal Hysteresis

The amount of hysteresis shift can be controlled by PC board (PCB) mounting. It has been proven experimentally that placing the voltage reference package near the PCB edge, especially the shortest edge or in a corner, reduce hysteresis effects due to the increased stiffness of the board. A PCB cutout reduces package stress and hysteresis shift.

3. Board Assembly Considerations

FGA reference PCB mounting exposes the device to temperatures that are outside the recommended operating range and absolute maximum sustained temperature exposure, but within the maximum temperature for the package. The resulting temperature cycle is more extreme than the normal thermal hysteresis stated on the datasheet, and therefore the output voltage shift can exceed the typical thermal hysteresis.

To characterize this effect, Renesas tested the FGA (5V output) for reflow shift. Ten devices were placed on a two-sided FR-4 PCB and then exposed to multiple assembly reflow cycles. Table 1 shows the results. The average reflow drift is approximately 300µV after the first reflow and 400µV at each successive reflow. This indicates the thermomechanical effects reach a maximum at some point, with an upper limit on the amount of shift. Although this data shows a consistent positive overall shift, it is possible at any cycle to have the V_{REF} voltage shift negative as well. Any shift in the V_{REF} output voltage can place it outside of the specified accuracy range as stated on the datasheet.

Table 1. Precision Voltage Reference Accuracy and Hysteresis Specs and Reflow Results

Unit	After 1 Reflow	After 2nd Reflow	After 3rd Reflow	After 4th Reflow
1	50	209	204	274
2	365	521	458	414
3	320	459	408	410
4	273	430	397	418
5	295	430	360	349
6	437	579	574	507
7	378	558	574	521
8	300	451	481	468
9	295	416	366	376
10	187	324	326	318

Renesas guarantees that the FGA reference complies with the datasheet specification when shipped to the customer, consistent with other semiconductor suppliers. Exposure to assembly thermal cycles is outside the scope of this datasheet. This is true for all voltage references of various technologies. Renesas has tested other precision voltage references from various suppliers and the results indicate that output voltage shift after reflow is a common trait. Figure 4 shows the test results.

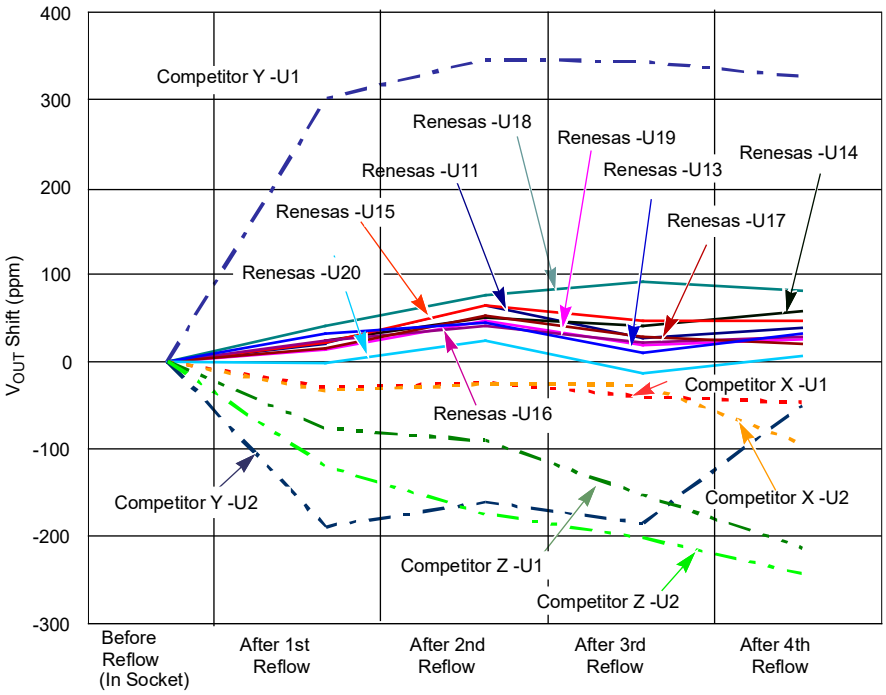


Figure 4. Reflow Shift Results for Renesas FGA and Other Reference Technologies

See Table 2 for a summary of initial accuracy and thermal hysteresis specifications and two-pass reflow test results for these precision reference devices. The right column compares the final tested voltage versus the datasheet specification. One device is clearly out of the specified limits and others are very close. Design engineers must consider the reference voltage accuracy after assembly.

Table 2. Precision Voltage Reference Accuracy and Hysteresis Specs and Reflow Results

Part	V_{OUT}	Initial Accuracy		Thermal Hysteresis		Output Voltage Range		Two Pass Reflow Results		Error from Ideal Value After Reflow
		%	mV	ppm	mV	MIN	MAX	$V_{INITIAL}$	V_{FINAL}	mV
Mfr X1	5.0	0.05%	2.5	N/A	N/A	4.9975	5.0025	4.999365	4.999245	-0.755
Mfr X2	5.0	0.05%	2.5	N/A	N/A	4.9975	5.0025	4.999742	4.999614	-0.386
Mfr Y1	5.0	0.04%	2.0	20	0.100	4.9980	5.0020	5.000663	5.002391	2.391
Mfr Y2	5.0	0.04%	2.0	20	0.100	4.9980	5.0020	5.000445	4.999643	-0.357
Mfr Z1	2.5	0.01%	0.5	15	0.038	2.4995	2.5005	2.500451	2.500225	0.225
Mfr Z2	2.5	0.01%	0.5	15	0.038	2.4995	2.5005	2.500297	2.499862	-0.138
Mfr W	5.0	0.02%	1.0	75	0.375	4.9990	5.0010	5.000790	5.000978	0.978
Renesas	5.0	0.01%	0.5	50	0.250	4.9995	5.0005	4.999945	5.000396	0.396

To minimize assembly reflow shift, reduce the peak reflow temperature below +260°C. The voltage reference can be hand solder to the PCB after the assembly process. Careful hand soldering reduce the peak temperature and exposure time for the package and reduce the post-assembly voltage shift. An additional advantage of hand soldering is that, if X-Ray inspection is required, the FGA reference is not subjected to that source of output voltage shift (see the related application note at www.renesas.com).

4. Conclusions

The FGA voltage reference provides excellent low-power performance and accuracy. Be aware of all the thermal aspects of device shift during assembly and normal operation, and plan the design accordingly. With proper planning and design, the FGA can yield a highly accurate and stable reference voltage.

5. Revision History

Revision	Date	Description
2.00	Nov 19, 2026	▪ Applied latest template ▪ Added Revision History section
1.00	Apr 9, 2010	Initial release

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