MEMSIC Out-of-Balance Application

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MEMSIC Inc.
Application Engineering Department
## Revision History

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1 Introduction

When washing machine dryer drum is in the speed ramping up stage, the drum will usually lost its balance due to the clothing inside the drum is not balanced distributed. This phenomenon is called Out-Of-Balance (OOB) of dryer drum.

The OOB will generate abnormal vibration to the washing machine, which will generate noise, even lead to damage to the mechanical structure of the washing machine, or damage the electrical motor and related circuit.

The traditional OOB detection solution on the washing machine is an indirect detection method, which cannot precisely reflect the actual vibration motion model on the dryer drum.

MEMSIC OOB Detection Module (with MEMSIC Accelerometer inside) is an innovational product, it can directly reflect the actual vibration model on the washing dryer drum by detecting the vibration acceleration in both X/Y plain axes. The unique “thermal based” technology of MEMSIC accelerometer can provide a higher resolution, stable output, lower noise and higher reliability, which can work better and reliably in the extremely tough environment in a washing machine.

MEMSIC worked with the world-class appliance companies to make the MEMSIC OOB solution productized and demonstrated its worthy on the washing machine to improve the overall performance, especially reach a quiet & stable operating result.

Following is some experiment that MEMSIC worked with the appliance companies to field measure the acceleration with MEMSIC OOB product when dryer drum running.
2 System Setup

2.1 Block Diagram

Chart 1 System Setup Block Diagram

2.2 System Setup description

- Mounting the MEMSIC OOB module on the washing machine dryer drum.
- The position & direction is like the Chart 1 diagram:
  - Dryer drum is in horizontal direction.
  - MEMSIC OOB module is mounted on the dryer drum outside shell. X/Y plain is in the rotation plane.
- The OOB acceleration output is reading by washing machine MCU. Sampling frequency is 20Hz (every 50mS). The acceleration data and associated motor RPM data is sent to PC via UART communication.
- The acceleration data was plotted in the chart below.
3 Experiment Data Plot

3.1 Data Plot

Chart 2 Acceleration/Deviation Data plotting vs RPM, Empty/Balanced case

Notes for Chart:

A Maxim deviation value in X axis.

B Maxim deviation value in Y axis.

C 1st system harmonic vibration spot in X axis, at about 300RPM.

D 1st system harmonic vibration spot in Y axis, at about 200RPM.
Chart 3 X-Axis Acceleration/Deviation Data plotting vs RPM, Out-Of-Balanced case

Notes for Chart:

A 1st system harmonic vibration spot in X axis, at about 320RPM, result the maxim vibration amplitude.

B 1st system vibration wave through spot in X axis, at about 490RPM, result the minimal vibration amplitude.

C 2nd system harmonic vibration spot in X axis, at about 570RPM, result the 2nd maxim vibration amplitude.

D The system is getting stable vibration in much smaller vibration amplitude with RPM increasing, it has passed the system harmonic range that can generate huge OOB shocking.
Chart 4 Y-Axis Acceleration/Deviation Data plotting vs RPM, Out-Of-Balanced case

Notes for Chart:

A 1\textsuperscript{st} system harmonic vibration spot in Y axis, at about 200RPM, result the maxim vibration amplitude.

B 1\textsuperscript{st} system vibration wave through spot in X axis, at about 350RPM, result the minimal vibration amplitude.

C 2\textsuperscript{nd} system harmonic vibration spot in X axis, at about 550RPM, result the 2\textsuperscript{nd} maxim vibration amplitude.

D The system is getting stable vibration in much smaller vibration amplitude with RPM increasing, it has passed the system harmonic range that can generate huge OOB shocking.
4 Summary of experiment

- The vibration behavior of washing machine dryer drum running (>80RPM) can be simulated as the harmonic motion in all 3-axis.
- The motion model depends on the actual mechanical suspension structure of the dryer drum.
- The 2 axes vertical to the drum rotation axis contribute the major OOB shock when dryer is running, so monitoring the vibration in the 2 axes can detect & control the OOB.
- The acceleration can directly reflect the vibration model.
- The vibration amplitude is directly according to the acceleration, the estimated formula is as following:

\[
\frac{Acc_{x/y}}{RPM^2} \propto Deviation_{x/y}
\]

- The MCU of washing machine can monitor the vibration based on the MEMSIC accelerometer data output, then take corresponding actions to reduce RPM to re-distribution the loading in the dryer drum, which will effectively reduce the abnormal shocking due to OOB happens.

- The competitive advantage based on the unique thermal technology will make MEMSIC accelerometer be suitable for washing machine OOB detection application:
  - **Monolithic CMOS MEMS design**: no actual movement part in the sensor, which make MEMSIC accelerometer can live in the tough situation with higher reliability, including higher shock survival (50,000g), and long term reliability with the whole life of washing machine device.
  - **Consistent zero-g offset drift over temperature performance**, which gives the constant zero offset reference point.
  - **Natural low-pass filter performance** to eliminate the higher-frequency noise that carried by the vibration, which could influence the major motion factor for motion detection.
  - **Digital output interface**, which will avoid the electrical noises generated by the dryer motor relay, will make the data transmission digitalized to eliminate the error.

Therefore, MEMSIC Out-Of-Balance module is the best and innovated solution for the OOB detection in washing machine dryer.