CASE 71

# Detector Switch Characterization Using the MTS

**Abstract:** This study confirmed the feasibility and improved discrimination of the multivariable Mahalanobis–Taguchi system (MTS) approach to detect and quantify the parameters specified. Based on the specified switch parameters, an MTS study was carried out with both good parts and bad production parts in order to select and to quantify the useful parameters that would be used for specifying and for checking the products at the lowest cost. Future evaluations will increase the sample size and the number of variables considered to improve the results. Implementation of this approach allows early detection of product performance (enabling shortened testing), detailed evaluation of product, and the potential to comprehend bias introduced by test conditions.

## 1. Introduction

The primary switch product types manufactured at Dole are tact, key, coding, rotary switches, and smart card connectors, designed for the communication, automotive, consumer, and industrial market. The KSM6 switch (Figure 1) was designed specifically to meet automotive market requirements as a switch to detect the portion of the ignition key in a high-end car model.

An engineering team was created to address the switch design and to improve its mechanical and electrical performances. The specification was defined with the customer according to the constraints given by the application. It was decided to use lots of parameters to characterize the product.

## 2. Background

The KSM6 is a detector switch with the following parameters (Figure 2): (1) force characteristics, (2) travel characteristics, (3), hysteresis performances between the ON and OFF curves, and (4) noise and bounces characteristics.

## 3. Objectives

As far as the KSM6 switch is concerned, we selected quite a lot of specified parameters necessary to guarantee both the quality and reliability of this product. Indeed, 19 parameters were chosen. The analytical objective for the Mahalanobis–Taguchi system approach was to reduce the number of parameters specified and to validate the characteristics according to the 19 parameters selected for the KSM6 product.

## 4. Experiment

The measurements were conducted in the ITT lab in Dole by using the *F/D method* (force–deflection electrical and mechanical measurements). It dealt with a traction/compression machine that enables it to establish the evolution curves of the component force according to the travel applied, thanks to an actuator. A connection enabled us to obtain the electric state of the product according to the same travel in the same way.

The F/D curve gave the points necessary to establish the mechanical and electrical characteristics

 *Taguchi's Quality Engineering Handbook.* Genichi Taguchi, Subir Chowdhury and Yuin Wu

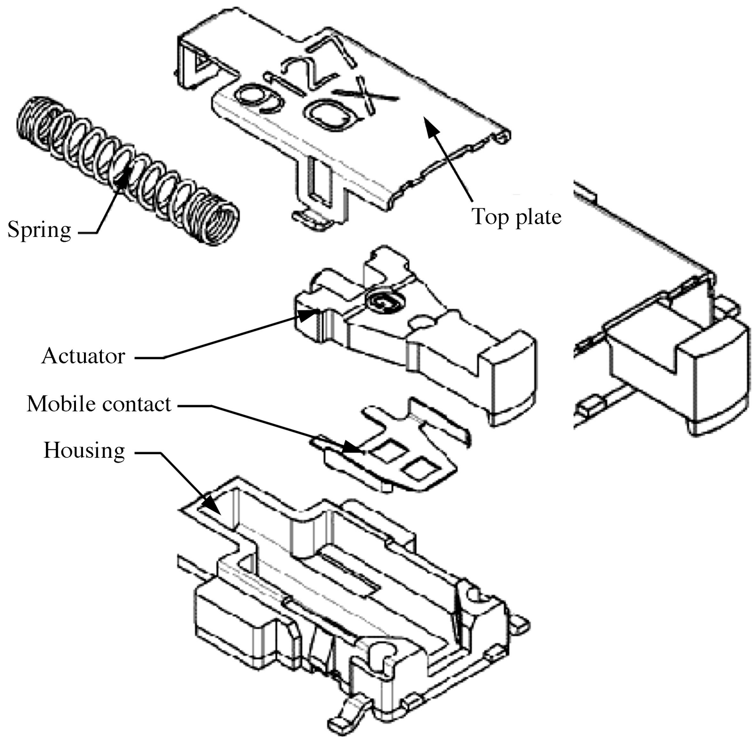


**Figure 1**
Three-dimensional and exploded assembly views of the KSM6 tact switch

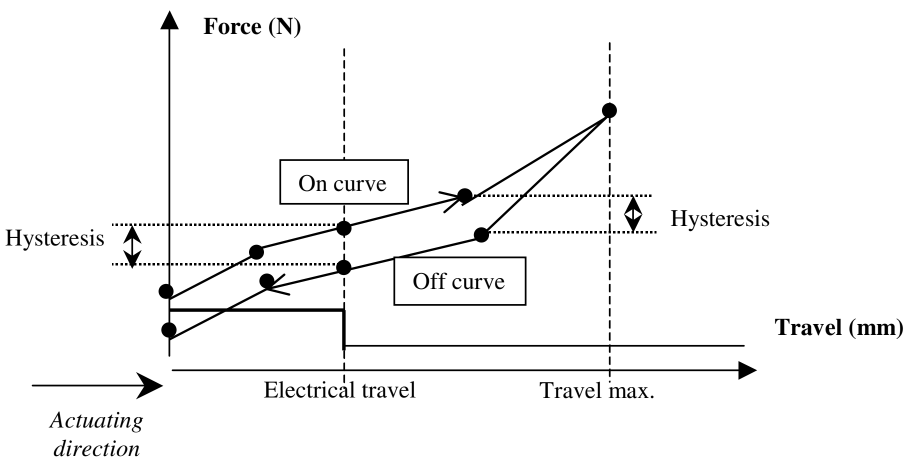


**Figure 2**
Typical force–deflection curve of the KSM6 switch

of the product. These characteristics allowed the validation of a product according to the specification (see Figure 3). This evaluation was based on switches coming from the assembly line. There were two groups: (1) good switches and (2) scrapped switches (rejected because of one or more parameters out the specification).

Following are the 19 specified parameters selected for the KSM6 switch:

1. Contact preload (N)
2. Fa (N)
3. Electrical travel ON (mm)
4. Electrical travel OFF (mm)
5. Mechanical travel (mm)
6. Electrical force ON (N)
7. Electrical force OFF (N)
8. Return force (N)
9. Force (at 1.85 mm)
10. Return force (at 1.85 mm)
11. Delta preload force/return force (N)
12. Delta electrical force ON/elect. force OFF (N)
13. Delta forces at 1.85 mm (N)
14. Noise beginning ON curve
15. Noise beginning OFF curve
16. Noise total ON curve
17. Noise total OFF curve
18. Contact resistance (mΩ)
19. Bounces (ms)

## 5. Mahalanobis Distance Calculations

The purpose of the MTS evaluation is to detect signal behavior outside the reference group. Existing data for the 19 characteristics of interest were organized for the 80 reference switches. The data were normalized for this group (Table 1) by considering the mean and standard deviation of this population of switches for each variable of interest:

$$Z_i = x_i - \frac{\overline{x}_i}{\sigma_i} \tag{1}$$

The correlation matrix was then calculated to comprehend all 19 variables and their respective correlations:

$$\mathbf{R} = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1k} \\ r_{21} & 1 & \cdots & r_{2k} \\ \vdots & \vdots & \cdots & \vdots \\ r_{k1} & r_{k2} & \cdots & 1 \end{bmatrix} \tag{2}$$

$$r_{ij} = \frac{\Sigma\ x_{i1} x_{j1}}{n} \qquad (1{:}\ 1,2,\ \ldots\ ,\ n)$$

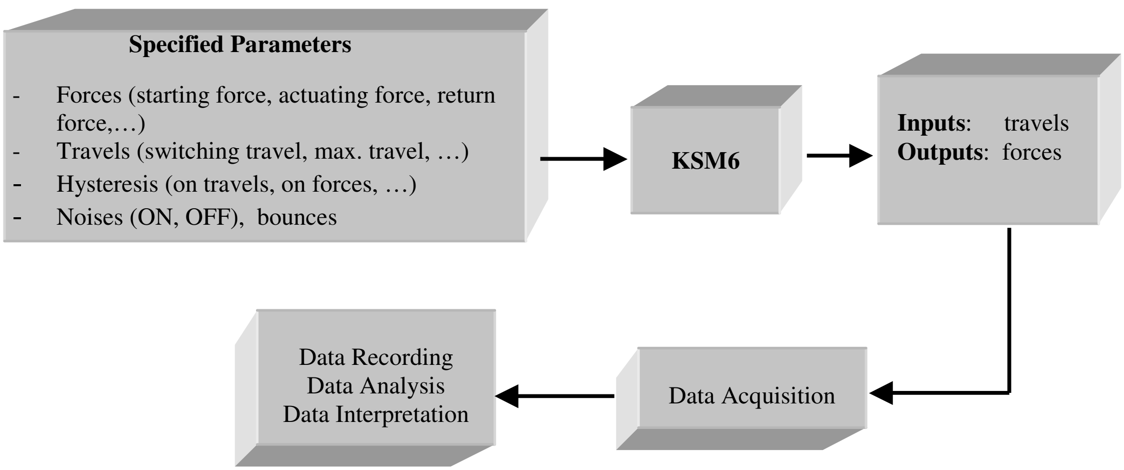


**Figure 3**
System, subsystems, and components

**Table 1**
Reference group output data normalization

| | Reference Data | | | | | Normalized Data | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **No.** | **Variable 1** $X_1$ | **Variable 2** $X_2$ | **Variable 3** $X_3$ | … | **Variable 19** $X_{19}$ | **Variable 1** $Z_1$ | **Variable 2** $Z_2$ | **Variable 3** $Z_3$ | … | **Variable 19** $Z_{19}$ |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| ⋮ | | | | | | | | | | |
| 80 | | | | | | | | | | |
| Mean | $\overline{X}_1$ | $\overline{X}_2$ | $\overline{X}_3$ | … | $\overline{X}_{19}$ | 0.0 | 0.0 | 0.0 | … | 0.0 |
| St. Dev. | $\sigma_1$ | $\sigma_2$ | $\sigma_3$ | … | $\sigma_{19}$ | 1.0 | 1.0 | 1.0 | … | 1.0 |

**Table 2**
Correlation matrix results for the reference group

| | | PRL 1 | FA 2 | CE ON 3 | CE OFF 4 | OM 5 | FOE ON 6 | FOE OFF 7 | FR 8 | FM ON 9 | FM OFF 10 | HYST1 11 | HYST2 12 | HYST3 13 | NB OFF 14 | NB ON 15 | NT ON 16 | NT OFF 17 | RC 18 | BOUN 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PRL** | **1** | 1.000 | 0.812 | 0.511 | 0.477 | −0.099 | 0.839 | 0.811 | −0.281 | 0.814 | 0.797 | 0.716 | 0.510 | 0.587 | −0.133 | −0.130 | −0.030 | −0.025 | −0.011 | 0.042 |
| **FA** | **2** | 0.812 | 1.000 | 0.770 | 0.734 | −0.063 | 0.968 | 0.942 | −0.733 | 0.983 | 0.961 | 0.869 | 0.569 | 0.753 | −0.057 | −0.236 | −0.100 | −0.096 | −0.012 | −0.002 |
| **CE ON** | **3** | 0.511 | 0.770 | 1.000 | 0.961 | 0.072 | 0.807 | 0.831 | −0.755 | 0.745 | 0.747 | 0.729 | 0.280 | 0.616 | −0.042 | −0.277 | −0.009 | −0.158 | −0.035 | 0.081 |
| **CE OFF** | **4** | 0.477 | 0.734 | 1.961 | 1.000 | 0.014 | 0.758 | 0.812 | −0.736 | 0.719 | 0.715 | 0.711 | 0.210 | 0.577 | −0.019 | −0.231 | −0.025 | −0.171 | 0.012 | 0.054 |
| **CM** | **5** | −0.099 | −0.063 | 0.072 | 0.014 | 1.000 | −0.056 | −0.030 | −0.025 | −0.143 | −0.151 | −0.001 | −0.114 | −0.204 | 0.006 | 0.179 | 0.112 | 0.007 | 0.041 | −0.067 |
| **FCE ON** | **6** | 0.839 | 0.968 | 0.807 | 0.758 | −0.056 | 1.000 | 0.937 | −0.668 | 0.956 | 0.932 | 0.846 | 0.602 | 0.766 | −0.072 | −0.290 | −0.083 | −0.107 | −0.017 | 0.056 |
| **FCE OFF** | **7** | 0.811 | 0.942 | 0.831 | 0.812 | −0.030 | 0.937 | 1.000 | −0.660 | 0.935 | 0.948 | 0.807 | 0.345 | 0.646 | −0.102 | −0.164 | −0.025 | −0.107 | 0.012 | 0.020 |
| **FR** | **8** | −0.281 | −0.733 | −0.755 | −0.736 | −0.025 | −0.668 | −0.650 | 1.000 | −0.705 | −0.705 | −0.792 | −0.419 | −0.577 | −0.085 | 0.196 | 0.127 | 0.127 | −0.105 | 0.044 |
| **FM ON** | **9** | 0.814 | 0.983 | 0.745 | 0.719 | −0.143 | 0.956 | 0.935 | −0.705 | 1.000 | 0.957 | 0.851 | 0.544 | 0.753 | −0.054 | −0.214 | −0.091 | −0.096 | 0.002 | 0.016 |
| **FM OFF** | **10** | 0.797 | 0.961 | 0.747 | 0.715 | −0.151 | 0.932 | 0.948 | −0.705 | 0.957 | 1.000 | 0.822 | 0.486 | 0.654 | −0.100 | −0.167 | −0.074 | −0.085 | 0.008 | 0.030 |
| **HYST1** | **11** | 0.716 | 0.869 | 0.729 | 0.711 | −0.001 | 0.846 | 0.807 | −0.792 | 0.851 | 0.822 | 1.000 | 0.549 | 0.674 | 0.009 | −0.298 | −0.066 | −0.083 | 0.092 | 0.005 |
| **HYST2** | **12** | 0.510 | 0.569 | 0.280 | 0.210 | −0.114 | 0.602 | 0.345 | −0.419 | 0.544 | 0.486 | 0.549 | 1.000 | 0.689 | 0.004 | −0.254 | −0.192 | −0.068 | −0.038 | 0.017 |
| **HYST3** | **13** | 0.587 | 0.753 | 1.616 | 1.577 | −0.204 | 0.766 | 0.646 | −0.577 | 0.753 | 0.654 | 0.674 | 0.689 | 1.000 | −0.026 | −0.330 | −0.187 | −0.124 | 0.050 | 0.004 |
| **NB OFF** | **14** | −0.133 | −0.057 | −0.042 | −0.019 | 0.006 | −0.072 | −0.102 | −0.085 | −0.054 | −0.100 | 0.009 | 0.004 | −0.026 | 1.000 | 0.038 | 0.073 | 0.309 | −0.080 | −0.007 |
| **NB ON** | **15** | −0.130 | −0.236 | −0.277 | −0.231 | 0.179 | −1.290 | −0.164 | 0.196 | −0.214 | −0.167 | −0.298 | −0.254 | −0.330 | 0.038 | 1.000 | 0.039 | 0.009 | −0.028 | −0.176 |
| **NT ON** | **16** | −0.030 | −0.100 | −0.009 | 0.025 | 0.112 | −0.083 | −0.025 | 0.127 | −0.091 | −0.074 | −0.006 | −0.192 | −0.187 | 0.073 | 0.039 | 1.000 | −0.009 | −0.122 | 0.050 |
| **NT OFF** | **17** | −0.025 | −0.096 | −0.158 | −0.171 | 0.007 | −0.107 | −0.107 | 0.127 | −0.096 | −0.085 | −0.083 | −0.068 | −0.124 | 0.309 | 0.009 | −0.009 | 1.000 | −0.033 | 0.010 |
| **RC** | **18** | −0.011 | 0.012 | 0.035 | 0.012 | 0.041 | −0.017 | 0.012 | −0.105 | 0.002 | 0.008 | 0.092 | −0.038 | 0.050 | −0.080 | −0.028 | −0.122 | −0.033 | 1.000 | −0.008 |
| **BOUN** | **19** | 0.042 | −0.002 | 0.081 | 0.054 | −0.067 | 0.056 | 0.020 | 0.044 | 0.016 | 0.030 | 0.005 | 0.017 | 0.004 | −0.007 | −0.176 | 0.050 | 0.010 | −0.008 | 1.000 |

Upon review of the correlation matrix (Table 2), it is clear that correlation between parameters exists. For this reason, the application of the multivariable Mahalanobis–Taguchi system approach makes sense because no single characteristic can describe the output fully.

The inverse of the matrix was then calculated:

$$\mathbf{R}^{-1} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1k} \\ a_{21} & a_{22} & \cdots & a_{2k} \\ \vdots & \vdots & & \vdots \\ a_{k1} & a_{k2} & \cdots & a_{kk} \end{bmatrix} \tag{3}$$

and finally the Mahalanobis distance:

$$\text{MD} = \frac{1}{k} Z R^{-1} Z^{\text{T}} \tag{4}$$

where $k$ is the number of characteristics, $Z$ the $1 \times 19$ normalized data vector, $R^{-1}$ the $19 \times 19$ inverse correlation matrix, and $Z^{\text{T}}$ the transposed vector ($19 \times 1$).

This completes the calculations of the normal group. All reference samples had MD distances of less than 2 (Table 3).

TMD for the abnormal samples was then calculated. Again the data were normalized, but now the mean and standard deviations of the reference group were considered. The inverse correlation matrix of the reference group solved previously was

**Table 3**
Mahalanobis distance values for the reference and abnormal groups

| Sample | Good Parts | Rejected Parts |
|---|---|---|
| 1 | 0.45588274 | 3.34905375 |
| 2 | 1.11503408 | 2.40756945 |
| 3 | 0.17740621 | 4.13031615 |
| 4 | 0.67630344 | 2.44623681 |
| 5 | 0.51367029 | 1.70684039 |
| 6 | 0.91088082 | 3.62376137 |
| 7 | 0.47617251 | 1.8801606 |
| 8 | 0.48574861 | 2.74470151 |
| 9 | 0.61893043 | 4.58774521 |
| 10 | 1.27624221 | 2.46283229 |
| 11 | 0.91560766 | |
| 12 | 0.73373554 | |
| 13 | 0.4391565 | |
| 14 | 0.37539039 | |
| 15 | 0.91071876 | |
| 16 | 0.29173633 | |
| 17 | 0.28862911 | |
| 18 | 0.40312754 | |
| 19 | 0.46821194 | |
| 20 | 0.29330727 | |
| ⋮ | ⋮ | |
| 60 | 0.24485985 | |
| 61 | 0.45349242 | |
| 62 | 0.22177811 | |
| 63 | 0.29027765 | |
| 64 | 0.08698667 | |
| 65 | 0.15542392 | |
| 66 | 0.31067779 | |
| 67 | 0.09868037 | |
| 68 | 0.34478916 | |
| 69 | 1.23338162 | |
| 70 | 0.45290798 | |
| 71 | 0.29085425 | |
| 72 | 0.76586855 | |
| 73 | 0.3832427 | |
| 74 | 1.15630344 | |
| 75 | 0.70401821 | |
| 76 | 0.15559801 | |
| 77 | 0.29566716 | |
| 78 | 0.81947543 | |
| 79 | 0.35900551 | |
| 80 | 2.58171136 | |

also used. The resulting MDs of the abnormal samples are summarized in Table 3.

## 6. Discussion

As is evident in the MDs of the abnormal samples, tremendous discrimination between good and bad switches was accomplished (Figure 4). To reduce data-processing complexity, it is desirable to consider fewer characteristics and eliminate those not contributing to product discrimination. Four out of 19 characteristics were selected as very important, and these characteristics were used all of the time and were not considered for screening. The other 15 characteristics were assigned to an $L_{16}$ array (Table 4).

All these 15 characteristics were considered at two levels. Level 1 used the variable to calculate the Mahalanobis distance, and level 2 did not use the variable to calculate the MD. Reconsideration of both the reference group and abnormal group MD was made for each run. The experiment design and results are shown in Table 4.

From these runs, SN ratios and mean responses were calculated for the main effects of each variable. As the goal was to improve discrimination, larger MDs were preferred and the larger-the-better SN ratio was used:

$$SN = \eta = -10 \log \left( \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y_i^2} \right) \qquad (5)$$

The data transformations gave the results shown in the response charts and ANOVA tables in xc-Figures and 6 and Table 5. Variables *A*, *C*, *F*, *G*, *I*, *J*, and *O* are shown to have little contribution to the SN ratio and could be considered for elimination. This would reduce the MD calculation to 12 characteristics. Some of the variables rejected contribute significantly to the mean, but as a whole, the effects of the factors on the mean compensate mutually to obtain a small variation to the mean (ca. 7%), which is fully acceptable. So we can confirm the choice of eliminated characteristics.

## 7. Confirmation

The confirmation method consists in doing the same MTS calculations by taking off the nonsignificant factors. By selecting only the significant factors, 12 out of 19 in our case, we created a new MTS graph (Figure 7). MD values for the normal and abnormal samples are shown in Table 6. The optimization evaluation gives very good results. Indeed, we can confirm that there is still a very good selection between the bad and the good pieces, even though we eliminated seven nonsignificant parameters.

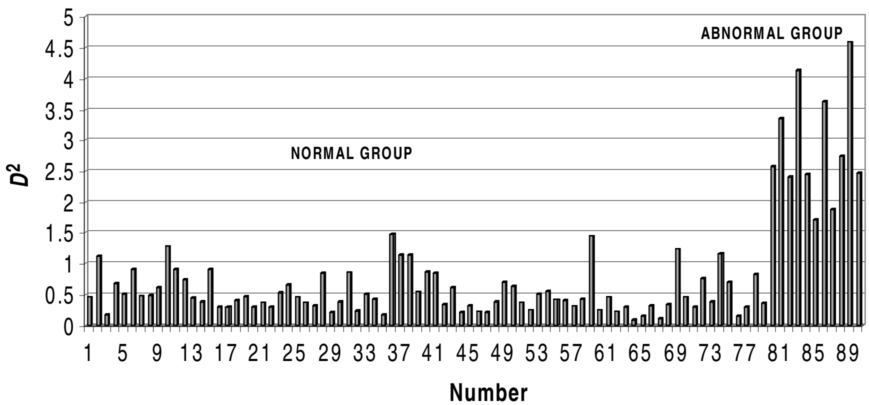


**Figure 4**
Mahalanobis distance for normal and abnormal groups

**Table 4**
MDs calculated for abnormal group within the $L_{16}$ orthogonal array

| | Factor | | | | | | | | | | | | | | | MD for 10 Abnormal Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* | *I* | *J* | *K* | *L* | *M* | *N* | *O* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3.349 | 2.408 | 4.13 | 2.446 | 1.707 | 3.624 | 1.88 | 2.745 | 4.588 | 2.463 |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5.066 | 3.555 | 3.507 | 2.848 | 2.09 | 4.867 | 2.506 | 0.235 | 7.818 | 0.726 |
| 3 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 4.615 | 1.247 | 1.826 | 3.466 | 1.209 | 2.64 | 2.28 | 2.403 | 7.784 | 0.805 |
| 4 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 4.213 | 1.19 | 2.264 | 3.437 | 1.548 | 2.866 | 2.633 | 3.762 | 7.788 | 3.278 |
| 5 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 5.198 | 1.873 | 6.523 | 3.057 | 1.443 | 1.094 | 1.203 | 0.918 | 7.835 | 0.56 |
| 6 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 4.404 | 1.541 | 2.829 | 2.241 | 0.796 | 1.089 | 1.021 | 4.061 | 7.822 | 3.894 |
| 7 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 4.492 | 2.8 | 1.141 | 2.645 | 2.029 | 3.73 | 1.035 | 2.965 | 7.799 | 3.23 |
| 8 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 4.321 | 2.906 | 1.658 | 3.11 | 2.435 | 4.467 | 1.204 | 2.898 | 7.791 | 0.586 |
| 9 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 4.842 | 3.027 | 4.105 | 3.384 | 1.983 | 1.426 | 2.37 | 2.825 | 7.81 | 3.474 |
| 10 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 4.183 | 2.941 | 3.128 | 1.898 | 1.318 | 1.366 | 2.146 | 3.102 | 7.849 | 0.617 |
| 11 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 5.135 | 0.668 | 1.337 | 2.097 | 1.548 | 5.294 | 2.334 | 1.094 | 7.8 | 0.911 |
| 12 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 5.262 | 1.117 | 2.499 | 3.1 | 2.092 | 4.619 | 2.166 | 3.782 | 7.804 | 3.809 |
| 13 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 4.878 | 1.251 | 4.353 | 2.739 | 1.657 | 4.367 | 2.037 | 2.648 | 7.826 | 0.552 |
| 14 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 4.119 | 1.045 | 3.491 | 1.422 | 1.475 | 4.627 | 1.534 | 3.672 | 7.794 | 3.371 |
| 15 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 4.621 | 2.465 | 1.894 | 1.644 | 1.415 | 2.481 | 1.483 | 4.436 | 7.794 | 3.705 |
| 16 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 4.383 | 2.847 | 2.668 | 2.976 | 2.037 | 2.78 | 1.962 | 0.504 | 7.793 | 0.531 |

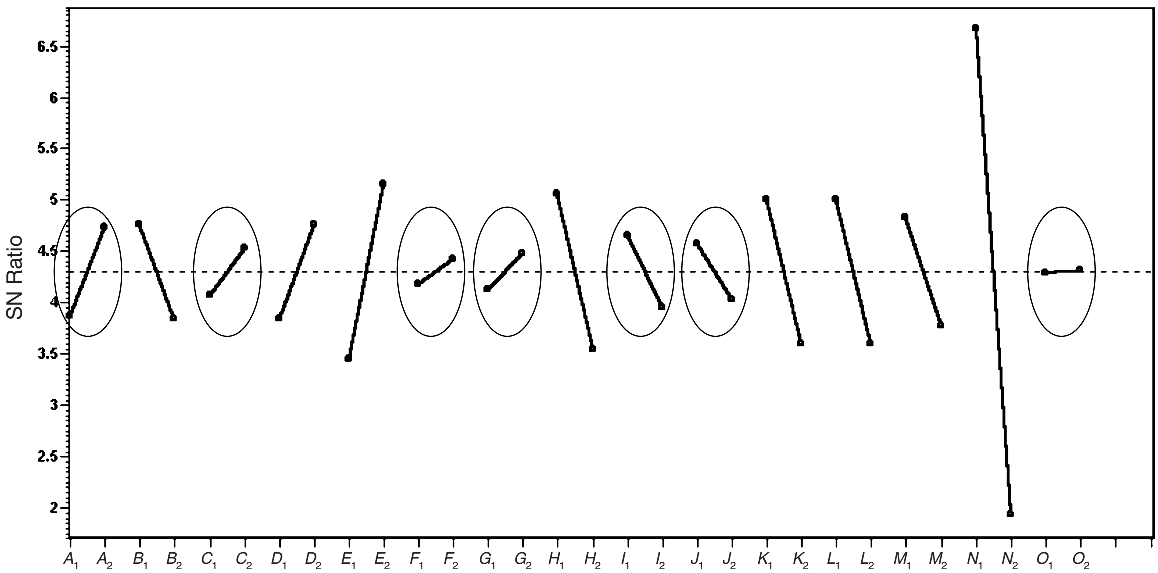


**Figure 5**
Response graph for the SN ratio

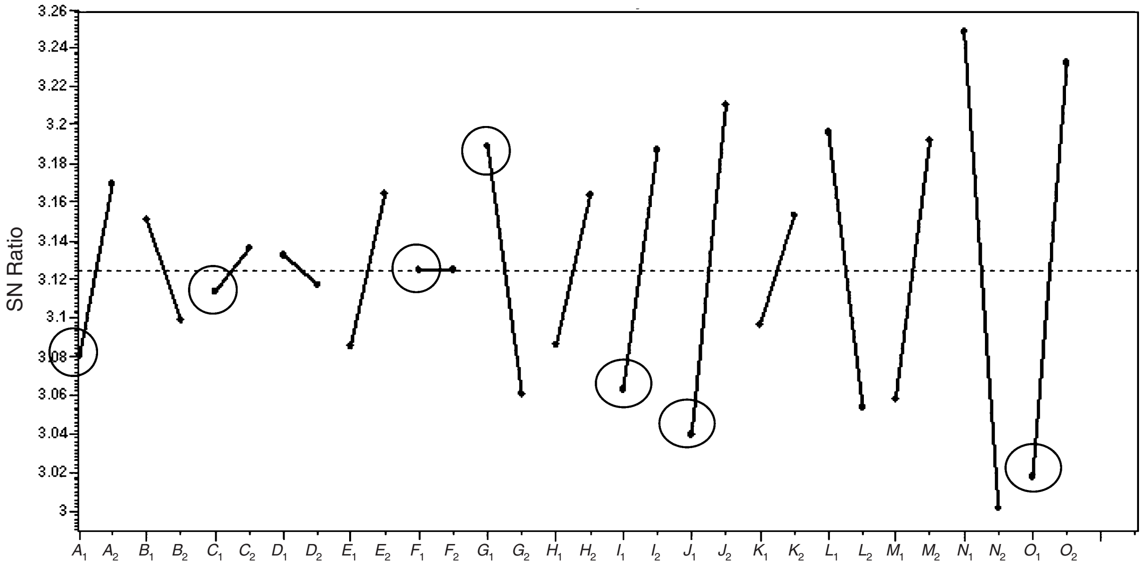


**Figure 6**
Response graph for the mean values

**Table 5**
ANOVA for the SN Ratio

| Source | d.f. | *S* | *V* | *F* | *S′* | *r* |
|---|---|---|---|---|---|---|
| *A* | 1 | 3.064 | 3.064 | | | |
| *B* | 1 | 3.3156 | 3.3156 | 2.9981 | 2.2097 | 1.53 |
| *C* | 1 | 0.8761 | 0.8761 | | | |
| *D* | 1 | 3.2996 | 3.2996 | 2.9836 | 2.1937 | 1.52 |
| *E* | 1 | 11.447 | 11.447 | 10.3507 | 10.341 | 7.15 |
| *F* | 1 | 0.2492 | 0.2492 | | | |
| *G* | 1 | 0.4806 | 0.4806 | | | |
| *H* | 1 | 9.0515 | 9.0515 | 8.1847 | 7.9456 | 5.49 |
| *I* | 1 | 1.9429 | 1.9429 | | | |
| J | 1 | 1.1272 | 1.1272 | | | |
| *K* | 1 | 7.9037 | 7.9037 | 7.1468 | 6.7978 | 4.7 |
| *L* | 1 | 7.9029 | 7.9029 | 7.146 | 6.797 | 4.7 |
| *M* | 1 | 4.342 | 4.342 | 3.9262 | 3.2361 | 2.24 |
| *N* | 1 | 89.7075 | 89.7075 | 81.1166 | 88.6016 | 61.23 |
| *O* | 1 | 0.0013 | 0.0013 | | | |
| $e_1$ | | | | | | |
| $e_2$ | | | | | | |
| (*e*) | 7 | 7.7414 | 1.1059 | | 16.5886 | 11.46 |
| Total | 15 | 144.7111 | 9.6474 | | | |

(*e*) is pooled error.

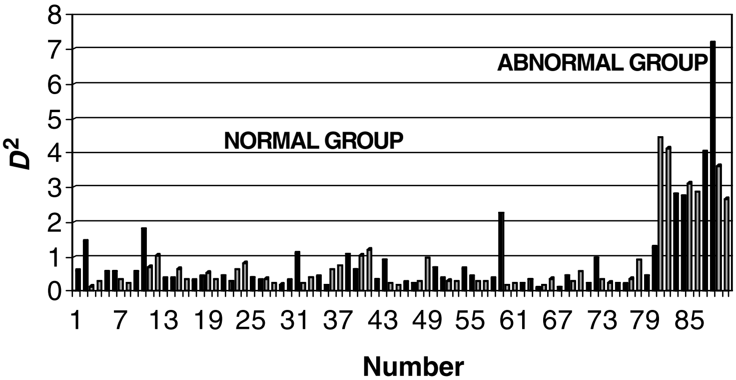


**Figure 7**
Mahalanobis distance for normal and abnormal groups

**Table 6**
Mahalanobis distance values for the reference and abnormal groups

| Sample | Good Parts | Rejected Parts |
|---|---|---|
| 1 | 0.58527515 | 4.4383654 |
| 2 | 1.42813712 | 4.15092412 |
| 3 | 0.15154057 | 2.82153352 |
| 4 | 0.29781518 | 2.75523643 |
| 5 | 0.54822524 | 3.12827267 |
| 6 | 0.5647138 | 2.88094718 |
| 7 | 0.32688929 | 4.01820264 |
| 8 | 0.24148032 | 7.18625986 |
| 9 | 0.5559233 | 3.62863953 |
| 10 | 1.80277538 | 2.67755672 |
| 11 | 0.70160571 | |
| 12 | 1.05331414 | |
| 13 | 0.36788692 | |
| 14 | 0.35625463 | |
| 15 | 0.64054606 | |
| 16 | 0.33201852 | |
| 17 | 0.31591459 | |
| 18 | 0.43327776 | |
| 19 | 0.53893526 | |
| 20 | 0.33842311 | |
| ⋮ | ⋮ | |
| 60 | 0.18403453 | |
| 61 | 0.22158889 | |
| 62 | 0.2094948 | |
| 63 | 0.3233402 | |
| 64 | 0.08915155 | |
| 65 | 0.16588856 | |
| 66 | 0.37570123 | |
| 67 | 0.11199467 | |
| 68 | 0.46124969 | |
| 69 | 0.28254858 | |
| 70 | 0.57035309 | |
| 71 | 0.2190487 | |
| 72 | 0.95366322 | |
| 73 | 0.32950224 | |
| 74 | 0.26453747 | |
| 75 | 0.22518346 | |
| 76 | 0.20727962 | |
| 77 | 0.35644774 | |
| 78 | 0.90913625 | |
| 79 | 0.44455372 | |
| 80 | 1.26760236 | |

## 8. Conclusions

The feasibility of applying the MTS approach has been demonstrated. In our present case we used it to characterize and to select the parameters specified for a detector switch. Indeed, thanks to this method, we were able to keep 12 specific parameters out of the 19 initially selected. The confirmation of the discrimination between the good and the bad switches without using the nonselected parameters was very good.

The MTS method was very helpful to eliminate the seven parameters from the specification and realize a significant reduction of the checking costs. In our case, we could reduce these costs by 37%, which corresponds to a $200,000 yearly profit.

## References

S. Rochon and P. Bouysses, October 1997. Optimization of the MSB series switch using Taguchi's parameter design method. Presented at the ITT Defense and Electronics Taguchi Symposium '97, Washington, DC.

S. Rochon and P. Bouysses, October 1999. Optimization of the PROXIMA rotary switch using Taguchi's parameter design method. Presented at the ITT Defense and Electronics Taguchi Symposium '99, Washington, DC.

S. Rochon and T. Burnel, October 1995. A three-step method based on Taguchi design of experiments to optimize robustness and reliability of ultra miniature SMT tact switches: the top actuated KSR series. Presented at the ITT Defense and Electronics Taguchi Symposium '95, Washington, DC.

S. Rochon and T. Burnel, October 2000. Optimization of the KMS ultraminiature switch using Taguchi's parameter design method. Presented at the ITT Defense and Electronics Taguchi Symposium 2000, Washington, DC.

S. Rochon, T. Burnel, and P. Bouysses, October 1999. Improvement of the operating life of the TPA multifunction switch using Taguchi's parameter design method. Presented at the ITT Defense and electronics Taguchi Symposium '99, Washington, DC.

S. Surface and J. Oliver II, 2001. Exhaust sensor output characterization using MTS. Presented at the 18th ASI Taguchi Methods Symposium.

G Taguchi, 1993. *Taguchi on Robust Technology Development*. New York: ASME.

G. Taguchi, S. Chowdhury, and Y. Wu, 2001. *The Mahalanobis–Taguchi System*. New York: McGraw Hill.

G. Taguchi, S. Chowdhury, and S. Taguchi, 1999. *Robust Engineering*. New York: McGraw-Hill.

*This case study is contributed by Sylvain Rochon.*