

# How to Identify Outliers in Excel Using Grubbs' Test

Authored by  
**stats writer**

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The identification and proper treatment of outliers are fundamental tasks in rigorous statistical analysis. An outlier is defined as an observation point that is distant from other observations, potentially indicating variability in measurement, experimental error, or a rare phenomenon. While simple visual inspection can sometimes identify extreme values, a formal statistical procedure is often required to confirm if a point is statistically significant enough to be classified as an outlier. One of the most widely accepted methods for this purpose is the Grubbs' Test, also known as the maximum normalized residual test.

The Grubbs' Test provides a hypothesis testing framework specifically designed to detect a single, significant outlier within a univariate data set assumed to follow an approximately normal distribution. The process of conducting this test--especially within accessible tools like **Microsoft Excel**--involves several structured steps: calculating basic descriptive statistics (mean and standard deviation), deriving the test statistic, and comparing it against a calculated critical value to reach a conclusion regarding the presence of the suspected extreme value.

This comprehensive guide details the mathematical theory behind the Grubbs' Test and provides a step-by-step methodology for its precise execution using the powerful functions available in **Excel**, ensuring clean and trustworthy results for your data analysis projects.

## Introduction to Grubbs' Test and Outlier Detection

The **Grubbs' Test**, often referred to as the G-test, serves as an essential statistical procedure for objectively identifying the presence of a single significant outlier within a given sample. Unlike simpler methods that rely solely on interquartile ranges, the G-test uses the mean and standard deviation of the sample to determine if the maximum or minimum value deviates too far from the central tendency to be considered part of the natural population variation. This test operates under the fundamental assumption that the sample data originates from an approximately normally distributed population.

To maintain statistical power and reliability, it is highly recommended that the data set under examination contains at least seven ( $n \geq 7$ ) observations. Datasets smaller than this threshold may yield less reliable results due to the inherent uncertainty associated with estimating population parameters from very small samples. When applying the Grubbs' Test, it is critical to confirm these prerequisites before proceeding with the calculations to ensure the validity of the hypothesis test.

**Note:** *It is imperative to remember that the G-test is strictly designed for the detection of **one** outlier. If preliminary analysis or domain knowledge strongly suggests the presence of multiple outliers in the dataset, the use of alternative robust methods, such as the Dixon Q Test or Rosner's Generalized Extreme Studentized Deviate Test (ESD), is advised to prevent masking effects where one outlier prevents the detection of others.*

## Mathematical Foundations: Calculating the Grubbs' Test Statistic (G)

The core of the Grubbs' Test lies in calculating the test statistic, G. This statistic essentially measures the magnitude of the largest deviation from the sample mean, relative to the sample standard deviation. The formula utilized depends on whether the analyst performs a one-sided test (suspecting the outlier is either the maximum or minimum value) or a two-sided test (where the outlier could be either extreme).

When the investigation focuses specifically on whether the largest value in the data set is the outlier, a one-sided test targeting the maximum extreme is performed. The numerator calculates the distance between the maximum observed value (xmax) and the sample mean (x). This difference is then normalized by dividing it by the sample standard deviation (s).

$$G = (x_{\max} - \bar{x}) / s$$

Conversely, if the minimum value in the dataset (xmin) is the suspicious point, the one-sided test focuses on the lower extreme. The formula maintains the positive nature of the G statistic by subtracting the minimum value from the sample mean, ensuring consistency in the interpretation of the resulting test value.

$$G = (\bar{x} - x_{\min}) / s$$

For situations where there is no pre-existing knowledge suggesting whether the outlier is high or low, the universally applicable two-sided test must be employed. This approach calculates the maximum absolute residual--the data point (xi) that deviates the furthest from the sample mean (x), regardless of direction. This maximum absolute difference is then standardized using the sample standard deviation.

$$G = \max |x_i - \bar{x}| / s$$

In all three variations, the calculation relies on:  $\bar{x}$ , representing the calculated sample mean, and  $s$ , representing the sample standard deviation. These preliminary calculations must be executed accurately in Excel prior to determining the G statistic.

## Determining Significance: The Critical Value (Gcritical)

To determine whether the calculated test statistic (G) is large enough to statistically reject the null hypothesis--which posits that there are no outliers--we must calculate the critical value (Gcritical). If the calculated G statistic exceeds Gcritical, we conclude with statistical confidence (based on the chosen significance level, typically  $\alpha = 0.05$ ) that the suspected value is indeed an outlier and should be treated accordingly.

The calculation of  $G_{critical}$  is mathematically complex and relies on the properties of the Student's t-distribution. The formula links the sample size ( $n$ ) to a specific t-distribution critical value ( $t_{critical}$ ) to establish the necessary threshold. The formula is structured as follows:

$$G_{critical} = (n-1)t_{critical} / \sqrt{n}$$

Crucially,  $t_{critical}$  represents the critical value derived from the t-distribution. This value requires specifying the degrees of freedom, which for the Grubbs' Test is always  $(n-2)$ . Furthermore, the required significance level ( $\alpha$ ) must be adjusted based on the sample size ( $n$ ) and whether a one-tailed or two-tailed test is being performed. This adjustment is essential because the Grubbs' Test is an extreme value test that inherently deals with the maximum deviation, necessitating a Bonferroni-type correction for multiple comparisons.

For a single-tail test (where the direction of the outlier is specified beforehand, i.e., max or min), the significance level used for the t-distribution lookup is  $\alpha/n$ . For the standard two-tailed test (where the outlier can be on either side), the adjusted significance level becomes  $\alpha/(2n)$ . Excel's statistical functions are vital for accurately determining this highly sensitive  $t_{critical}$  value.

### Practical Example: Setting up the Data in Excel

To demonstrate the robust application of the Grubbs' Test, consider a practical scenario where we must rigorously determine if the observation value of 60 within a sample set is a statistically significant outlier. We will use a standard significance level ( $\alpha$ ) of 0.05 for this demonstration. The initial step requires organizing the data efficiently within an Excel spreadsheet, as shown in the image below, to prepare for the statistical calculations.

	A	B	C	D
1	Raw Data			
2	5			
3	10			
4	12			
5	14			
6	15			
7	15			
8	14			
9	13			
10	19			
11	17			
12	16			
13	20			
14	22			
15	8			
16	21			
17	28			
18	11			
19	9			
20	29			
21	60			
22				

**Step 1: Verify Normal Distribution Assumption.** Before performing any parametric test like the G-test, it is mandatory to confirm that the underlying data set is approximately normally distributed. While formal tests like the Shapiro-Wilk test exist, a simple and effective preliminary check in Excel involves creating a **histogram**. This visual representation allows us to quickly assess if the data distribution roughly approximates the characteristic bell-shape of the normal distribution.

To generate the histogram, utilize Excel's Data Analysis ToolPak. The subsequent screenshots illustrate the process of generating this graphical check. Visual confirmation of a roughly symmetric, bell-shaped distribution supports proceeding with the Grubbs' Test; significant skewness or multimodality would necessitate alternative non-parametric outlier detection methods.

	A	B	C	D	E	F	G	H	I
1	Raw Data		bins						
2	5		5						
3	10		10						
4	12		15						
5	14		20						
6	15		25						
7	15		30						
8	14								
9	13								
10	19								
11	17								
12	16								
13	20								
14	22								
15	8								
16	21								
17	28								
18	11								
19	9								
20	29								
21	60								

**Histogram** ? X

**Input**

Input Range:

Bin Range:

Labels

**Output options**

Output Range:

New Worksheet Ply:

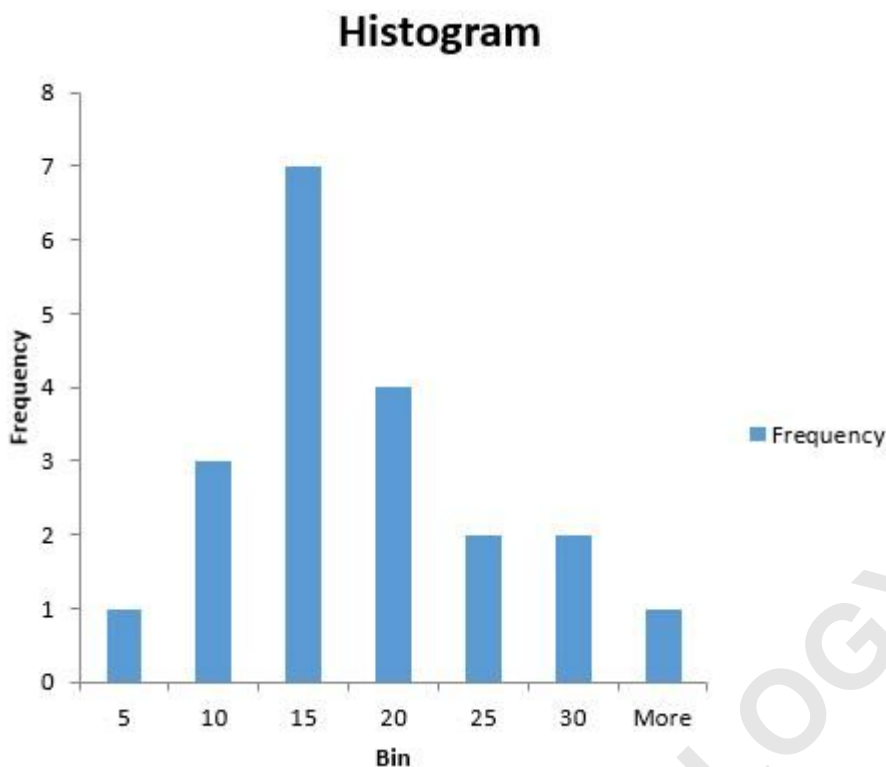
New Workbook

Pareto (sorted histogram)

Cumulative Percentage

Chart Output

OK Cancel Help



## Calculation of Statistical Parameters in Excel

The successful execution of the Grubbs' Test in Excel requires the accurate calculation of several key statistical values, which will serve as inputs for the G statistic and the  $G_{critical}$  formula. These calculations can be easily performed using built-in Excel functions adjacent to the raw data column.

**Sample Size (n):** Count the total number of observations in the dataset using the `=COUNT()` function. This value is essential for both the numerator and the denominator of the critical value calculation.

**Sample Mean ( $\bar{x}$ ):** Calculate the average of all data points using the `=AVERAGE()` function. The mean acts as the center point of the distribution from which the potential outlier deviation is measured.

**Sample Standard Deviation (s):** Determine the spread of the data using the `=STDEV.S()` function (assuming the data is a sample, which is standard practice for outlier detection). This standard deviation is the crucial normalizing factor in the G statistic formula.

**Maximum Value ( $x_{max}$ ):** Identify the largest value using `=MAX()`. Since 60 is the suspected outlier and is the highest value in the set, we anticipate performing a one-sided test targeting the maximum extreme, though the two-sided test is safer if in doubt.

These preliminary calculations establish the foundation necessary to compute the G statistic. For our specific example where 60 is the maximum observed value, we will use the one-sided formula:  $G = (x_{\max} - \bar{x}) / s$ .

## Practical Example: Calculating G and Gcritical in Excel

**Step 2: Perform the Grubbs' Test Calculations.** With the preliminary statistics established, we proceed to calculate the two critical components of the hypothesis test: the **Test Statistic (G)** and the **Critical Value (Gcritical)**. The complexity of the Gcritical formula necessitates the use of Excel's inverse T-distribution function,  $T.INV.2T$ , to determine  $t_{\text{critical}}$ . Remember that for the two-sided test, the significance level ( $\alpha=0.05$ ) must be adjusted to  $\alpha/(2n)$ . The implementation of these formulas is detailed in the screenshot provided.

	A	B	C	D	E
1	Raw Data		Max	60	=MAX(A2:A21)
2	5		Mean	17.9	=AVERAGE(A2:A21)
3	10		Standard Deviation	11.684	=STDEV.S(A2:A21)
4	12		G	3.603219	=(D1-D2)/D3
5	14				
6	15		Alpha	0.05	
7	15		Sample Size	20	=COUNT(A2:A21)
8	14		Significance Value	0.0025	=D6/D7
9	13		Degrees of Freedom	18	=D7-2
10	19		t-Critical Value	3.196574	=T.INV(1-D8, D9)
11	17		G-Critical Value	2.556581	=(D7-1)*D10/SQRT(D7*(D9+D10^2))
12	16				
13	20				
14	22				
15	8				
16	21				
17	28				
18	11				
19	9				
20	29				
21	60				
22					

Upon execution of the formulas shown above, we obtain the key results. The calculated **Test Statistic, G**, found in cell D4, is determined to be **3.603219**. This value represents how many standard deviations the suspected outlier (60) lies from the sample mean.

Simultaneously, the necessary **Critical Value, Gcritical**, displayed in cell D11, is calculated to be

**2.556581.** This figure establishes the boundary required for statistical significance at the  $\alpha = 0.05$  level, accounting for the sample size and the necessary statistical corrections inherent to the Grubbs' Test methodology.

**Step 3: Interpretation and Conclusion.** The final step involves comparing the calculated G statistic against the  $G_{critical}$  threshold. Since our calculated test statistic ( $G = 3.603219$ ) is demonstrably greater than the critical value ( $G_{critical} = 2.556581$ ), we confidently reject the null hypothesis. The statistical conclusion is that the value 60 is indeed a significant outlier within this dataset, requiring further investigation or specific data treatment.

## Handling Outliers After Identification

Once the Grubbs' Test definitively identifies an outlier, the analytical work is not complete. The mere identification does not justify automatic removal; rather, it initiates a critical phase of investigation to understand the cause of the extreme value. The decision on how to treat the outlier depends entirely on its determined origin--whether it stems from an error or represents a genuine, albeit rare, observation.

Analysts typically have three primary courses of action when confronted with a statistically significant outlier, each carrying distinct implications for the final results:

**Verification for Error:** The immediate first step is a thorough **double-check to confirm that the value is not merely a typo or a data entry error**. Simple mistakes during manual data input are a frequent cause of apparent outliers. Returning to the original source data or checking the measurement process can validate the accuracy of the suspicious figure before any statistical manipulation is considered.

**Imputation or Assignment:** If the outlier turns out to be a result of a typo or data entry error, you may decide to assign a new value to it, such as the **mean** or median of the dataset. This is a form of data imputation that minimizes the impact of the error while retaining the observation point.

**Removal of the Outlier:** If the value is a true outlier, you may choose to **remove the outlier** if it will have a significant impact on your overall analysis, particularly if it represents a process failure or contamination event that should not influence the remaining data population metrics.

Regardless of the chosen method--be it correction, imputation, or removal--it is an absolute requirement of rigorous scientific reporting to document the decision process meticulously. When presenting the final conclusions of the analysis, always make a clear note regarding the detection, investigation, and final treatment of any identified outliers to ensure transparency and reproducibility of the results.