Data Analysis Expressions (DAX)
In PowerPivot for Excel 2010

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B. Executive Summary

There are millions of Microsoft Excel users who are familiar with using Excel formulas to perform calculations. Those calculations may be as simple as adding up a column of numbers, or they may be far more complex simulations of various business models. But in every case, each formula is built using a combination of basic operators and functions that are provided within Excel as the building blocks for such formulas.

PowerPivot for Excel provides the building blocks needed to build business intelligence solutions, whether those solutions use simple calculations or something significantly more complex. The building blocks include the ability to import data tables from a wide variety of data sources, the ability to perform calculations on large volumes of in-memory data quickly, the ability to author custom calculations using the DAX (Data Analysis Expressions) language, and the ability to use the result of those calculations in Excel PivotTables.

Data Analysis Expressions are very similar to Excel formulas, and there is considerable overlap between the list of DAX functions and Excel functions. But there are significant differences, and many new functions in DAX that don’t exist within Excel. These functions are designed to offer capabilities that focus on data analysis, particularly for related tables of data, and for dynamic analysis. The ability to define calculations that will be evaluated dynamically in many different contexts is a powerful tool, and prior to PowerPivot and DAX, these sorts of calculations often involved more complex multi-dimensional concepts and languages.

With Data Analysis Expressions, it is our hope that Excel users will be able to easily learn how to perform data analysis, using DAX formulas that look a lot like Excel formulas, but that provide additional capabilities, and that are much easier to learn and use than the multi-dimensional constructs more generally used by IT professionals to perform this sort of data analysis.

This paper outlines the use of DAX formulas in PowerPivot, and describes the many new DAX functions. In addition to covering the functions themselves, there is a discussion of the important concepts that any PowerPivot user will want to know. It is hoped that this paper might be a good way to become familiar with the basics of the DAX formula language.

C. Background

1. PowerPivot

Microsoft's Analysis Services product team (in the SQL Server division) has developed a new product that provides self-service BI (Business Intelligence) functionality for users of Microsoft Office. This product is generally referred to as "PowerPivot" and it consists of both a client-side component (PowerPivot for Excel) and also a server side component (PowerPivot for SharePoint).

PowerPivot for Excel is an add-in for Microsoft Office Excel 2010 that is available as a free download from the web at http://powerpivot.com. The idea is that Excel users can install this add-in and start using PowerPivot on a stand-alone basis. When users want to share the results of their work, they will publish their workbooks to SharePoint servers that have the server side component installed.

PowerPivot for SharePoint is an add-in for Microsoft SharePoint that is available as part of Microsoft SQL Server 2008 R2. When it is installed on top of SharePoint and used in conjunction with Excel Services, it provides a platform for publishing and sharing PowerPivot workbooks.

Introducing PowerPivot for Excel 2010

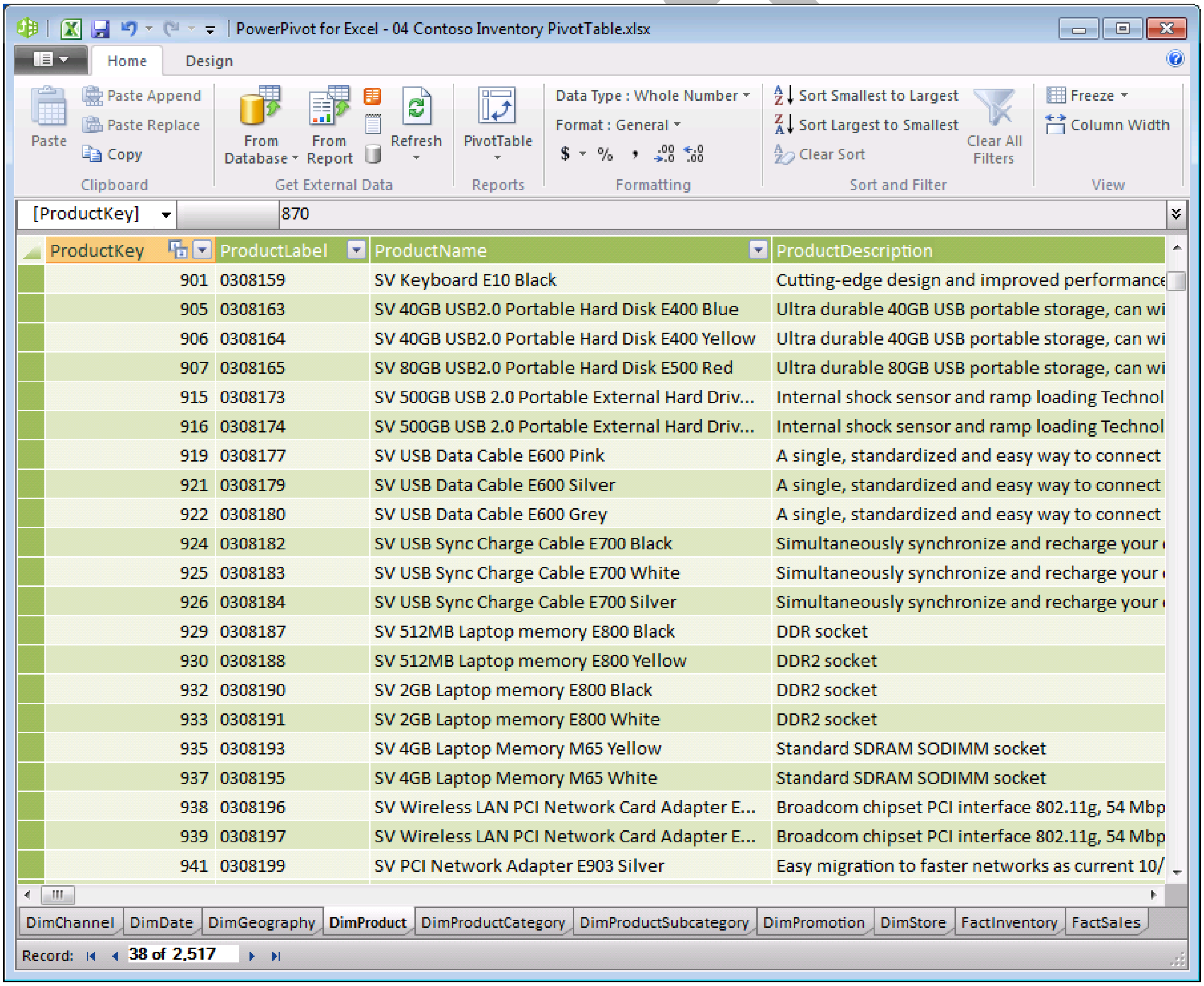
Microsoft PowerPivot for Excel 2010, formerly known as Project "Gemini", is a data analysis add-in that delivers unmatched computational power directly within Microsoft Excel 2010.

PowerPivot gives users the power to create compelling self-service BI solutions, facilitates sharing and collaboration on user-generated BI solutions in a Microsoft SharePoint Server 2010 environment, and enables IT organizations to increase operational efficiencies through Microsoft SQL Server 2008 R2-based management tools.

2. PowerPivot for Excel

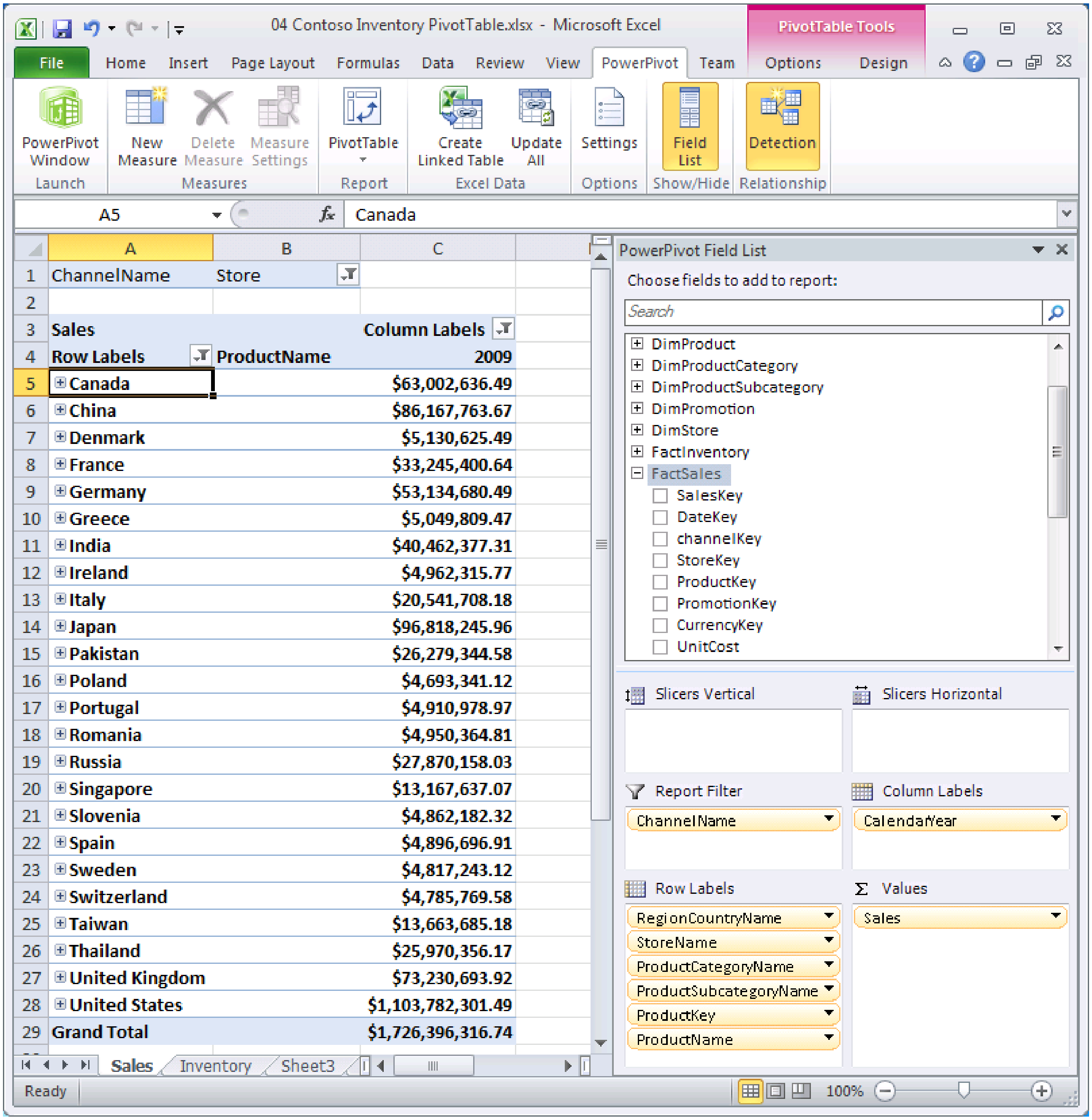
The client experience in PowerPivot for Excel includes two key pieces of functionality (an in-memory database built using a relational data model, and a rich PivotTable authoring experience,) which are encapsulated in two significant UI components, the PowerPivot Window and the PowerPivot Field List. Note that the information presented here is meant to provide the context in which Excel users author Data Analysis Expressions (DAX) and is not meant to be a complete enumeration of the features in PowerPivot.

PowerPivot Window is the window in which users build a relational data model. This window displays tables of data (each using its own sheet, with tabs along the bottom,) and is the place where tables are imported, relationships are created, column data types and formats are maintained, and generally is the place where you may view the underlying data being used in the data model.



ProductKey	ProductLabel	ProductName	ProductDescription
901	0308159	SV Keyboard E10 Black	Cutting-edge design and improved performanc
905	0308163	SV 40GB USB2.0 Portable Hard Disk E400 Blue	Ultra durable 40GB USB portable storage, can wi
906	0308164	SV 40GB USB2.0 Portable Hard Disk E400 Yellow	Ultra durable 40GB USB portable storage, can wi
907	0308165	SV 80GB USB2.0 Portable Hard Disk E500 Red	Ultra durable 80GB USB portable storage, can wi
915	0308173	SV 500GB USB 2.0 Portable External Hard Driv...	Internal shock sensor and ramp loading Technol
916	0308174	SV 500GB USB 2.0 Portable External Hard Driv...	Internal shock sensor and ramp loading Technol
919	0308177	SV USB Data Cable E600 Pink	A single, standardized and easy way to connect
921	0308179	SV USB Data Cable E600 Silver	A single, standardized and easy way to connect
922	0308180	SV USB Data Cable E600 Grey	A single, standardized and easy way to connect
924	0308182	SV USB Sync Charge Cable E700 Black	Simultaneously synchronize and recharge your
925	0308183	SV USB Sync Charge Cable E700 White	Simultaneously synchronize and recharge your
926	0308184	SV USB Sync Charge Cable E700 Silver	Simultaneously synchronize and recharge your
929	0308187	SV 512MB Laptop memory E800 Black	DDR socket
930	0308188	SV 512MB Laptop memory E800 Yellow	DDR2 socket
932	0308190	SV 2GB Laptop memory E800 Black	DDR2 socket
933	0308191	SV 2GB Laptop memory E800 White	DDR2 socket
935	0308193	SV 4GB Laptop Memory M65 Yellow	Standard SDRAM SODIMM socket
937	0308195	SV 4GB Laptop Memory M65 White	Standard SDRAM SODIMM socket
938	0308196	SV Wireless LAN PCI Network Card Adapter E...	Broadcom chipset PCI interface 802.11g, 54 Mbp
939	0308197	SV Wireless LAN PCI Network Card Adapter E...	Broadcom chipset PCI interface 802.11g, 54 Mbp
941	0308199	SV PCI Network Adapter E903 Silver	Easy migration to faster networks as current 10/

PowerPivot Field List is a task pane that is loaded in Excel as a replacement for Excel's PivotTable field list. When a user builds an Excel PivotTable that is bound to data in the PowerPivot window, instead of showing the standard Excel field list, we show the PowerPivot field list which has additional capabilities.



Canada

	A	B	C
1	ChannelName	Store	
2			
3	Sales		Column Labels
4	Row Labels	ProductName	2009
5	⊞ Canada		$63,002,636.49
6	⊞ China		$86,167,763.67
7	⊞ Denmark		$5,130,625.49
8	⊞ France		$33,245,400.64
9	⊞ Germany		$53,134,680.49
10	⊞ Greece		$5,049,809.47
11	⊞ India		$40,462,377.31
12	⊞ Ireland		$4,962,315.77
13	⊞ Italy		$20,541,708.18
14	⊞ Japan		$96,818,245.96
15	⊞ Pakistan		$26,279,344.58
16	⊞ Poland		$4,693,341.12
17	⊞ Portugal		$4,910,978.97
18	⊞ Romania		$4,950,364.81
19	⊞ Russia		$27,870,158.03
20	⊞ Singapore		$13,167,637.07
21	⊞ Slovenia		$4,862,182.32
22	⊞ Spain		$4,896,696.91
23	⊞ Sweden		$4,817,243.12
24	⊞ Switzerland		$4,785,769.58
25	⊞ Taiwan		$13,663,685.18
26	⊞ Thailand		$25,970,356.17
27	⊞ United Kingdom		$73,230,693.92
28	⊞ United States		$1,103,782,301.49
29	Grand Total		$1,726,396,316.74

PowerPivot Field List

Choose fields to add to report:

Search

- ⊞ DimProduct
- ⊞ DimProductCategory
- ⊞ DimProductSubcategory
- ⊞ DimPromotion
- ⊞ DimStore
- ⊞ FactInventory
- ⊟ FactSales
  - □ SalesKey
  - □ DateKey
  - □ channelKey
  - □ StoreKey
  - □ ProductKey
  - □ PromotionKey
  - □ CurrencyKey
  - □ UnitCost

Slicers Vertical

Slicers Horizontal

Report Filter: ChannelName

Column Labels: CalendarYear

Row Labels: RegionCountryName, StoreName, ProductCategoryName, ProductSubcategoryName, ProductKey, ProductName

Values: Sales

Excel and PowerPivot are used together to construct a workbook that contains a data model.

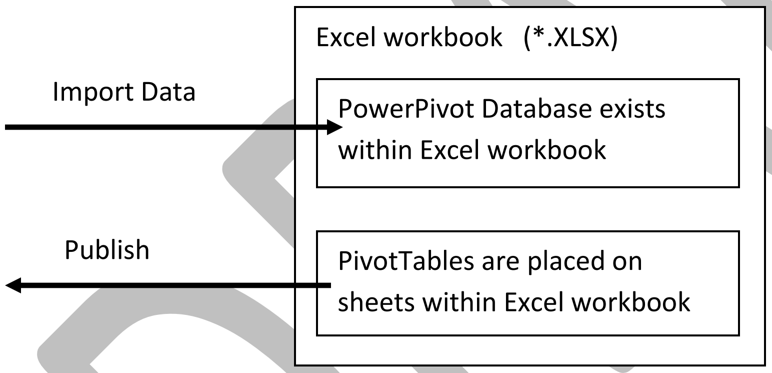
1. The PowerPivot database is a set of tables that are loaded in memory and saved into an Excel workbook. When loaded in memory, these tables are viewed in the PowerPivot window, not on Excel's worksheets.

2. The tables are imported from a variety of external data sources, including databases, other workbooks, text files, data feeds, and others.

3. The tables are related to each other via relationships. Relationships may be imported along with the data, or they may be created within the PowerPivot window.

4. Additional calculations may be added to the database, either as calculated columns for tables, or as measures that will be evaluated in PivotTables, using the DAX formula language (the topic of this paper).

5. When the workbook is published to SharePoint, and the SharePoint server has PowerPivot for SharePoint installed, then the database is loaded into memory on the server, and users may work with PivotTables using a web browser.

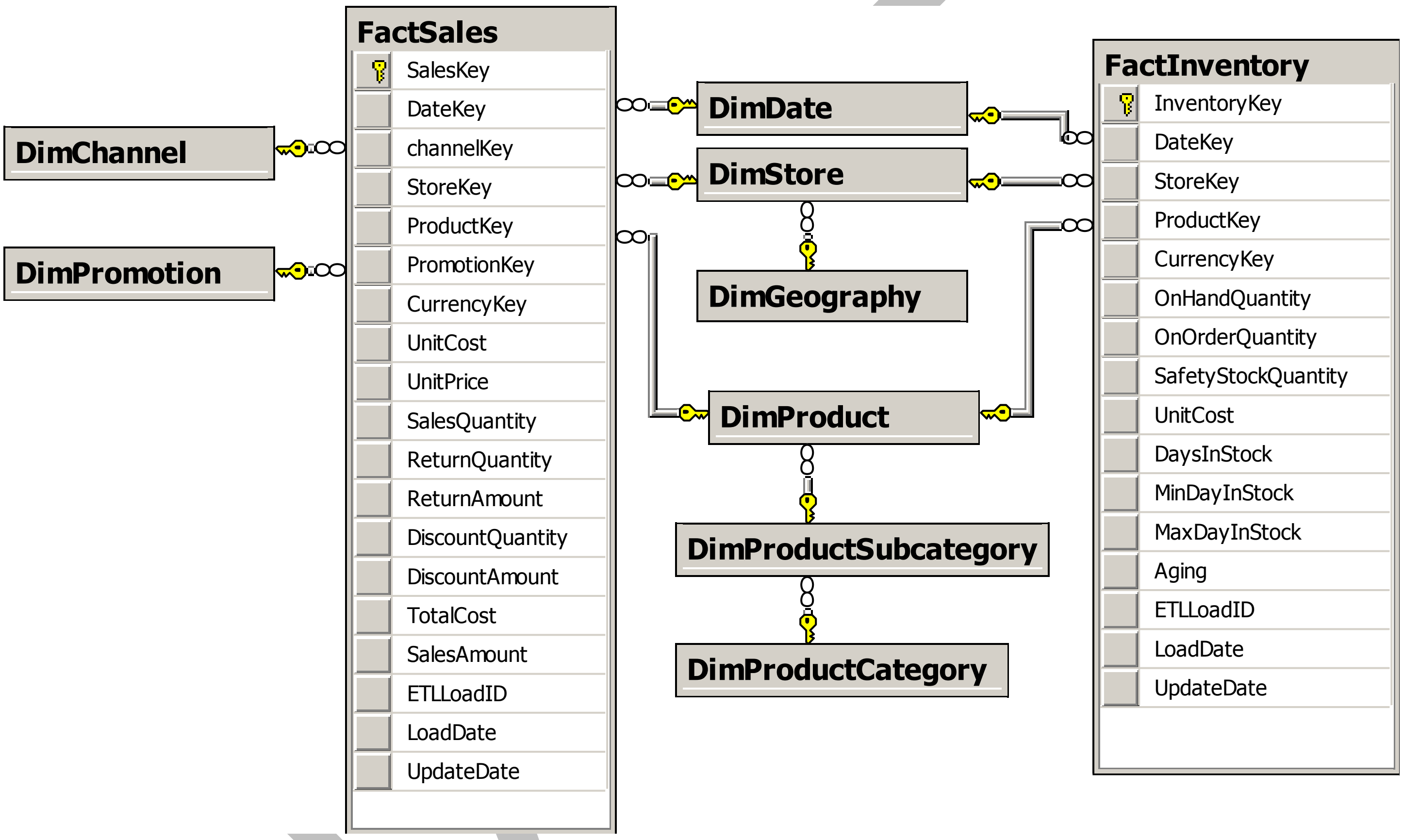

Excel workbook (*.XLSX)
Import Data
PowerPivot Database exists within Excel workbook
Publish
PivotTables are placed on sheets within Excel workbook

3. Samples – Contoso Database

The samples used as illustrations in this document all come from an Excel workbook that imported its relational data from the “Contoso” SQL Server relational database that is available from the Microsoft Download Center as part of Microsoft Contoso BI Demo Dataset for Retail Industry:

http://www.microsoft.com/downloads/details.aspx?displaylang=en&FamilyID=868662dc-187a-4a85-b611-b7df7dc909fc

To build the sample workbook, I brought in data from ten (10) of the tables in the Contoso database:



There are two tables of transactions in this data: FactSales and FactInventory. (This explains why the samples in this paper illustrate Sales and/or Inventory scenarios.) The other eight tables are related to one or both of the transaction (fact) tables as shown in the diagram above.

This sample data set contains approx 3.4 million sales transactions and more than 8 million inventory transactions. When loaded into an Excel workbook using PowerPivot, it illustrates two very compelling advantages of PowerPivot for data analysis over simple Excel PivotTables in Excel:

- The ability to base a PivotTable on a set of multiple tables (as opposed to a single flattened table).
- The ability to consume far larger data volumes (more rows) than can fit within an Excel worksheet.

D. Data Analysis Expressions (DAX) – The Basics

1. DAX Goals

The ultimate goal of PowerPivot for Excel is to make data analysis really easy. Unlike products that are designed for IT professionals, (for example: Microsoft SQL Server Analysis Services,) PowerPivot for Excel is intended to be used by the same folks who build Excel PivotTables today. The idea is that Excel users should be able to leverage the training and experience they already have and should not be required to learn complex multi-dimensional concepts nor specialized multi-dimensional languages.

With this in mind, DAX was implemented within PowerPivot to achieve the following:

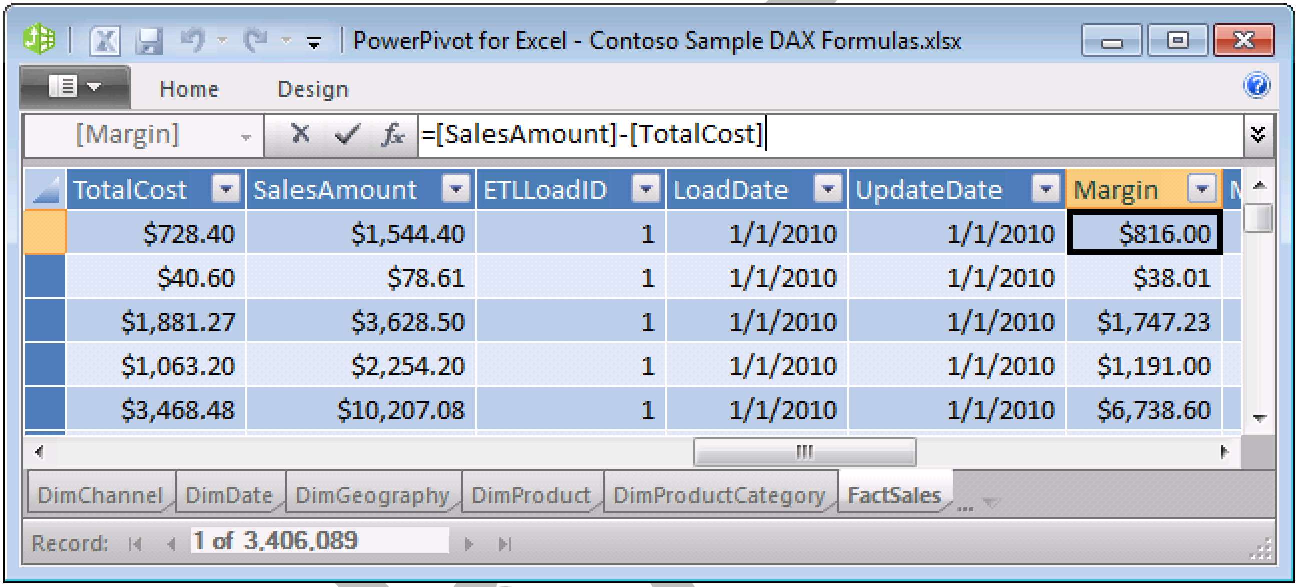
- Ease-Of-Use   DAX uses standard Excel formula syntax (and some of Excel's functions)
- Relational Data   Simple relational data model based on tables, columns, and relationships
- PivotTables   Analysis performed via PivotTables based on the database (multiple tables)

2. DAX Calculations - Calculated Columns and Measures

In every case, a DAX formula is used to define a field that will be placed somewhere on an Excel PivotTable. There are two types of fields that can be placed on a PivotTable: **columns** and **measures**.

Calculated Columns are columns that are defined in the PowerPivot window by providing a column name and a DAX expression. Calculated Columns are populated with values when they are defined and become just like any other column in a table, except that regular (non-calculated) columns are usually imported from an external data source while calculated columns are calculated after the regular columns have been loaded. The values from a column may be placed onto a PivotTable's row labels or column labels or may be placed in a PivotTable's filter/slicer to control the portion of the data that will be used in the analysis. Finally a column may be used as part of the calculation that defines a measure (described below). Here are a couple of simple calculated columns:

1) [Margin] defined as: =[SalesAmount]-[TotalCost]

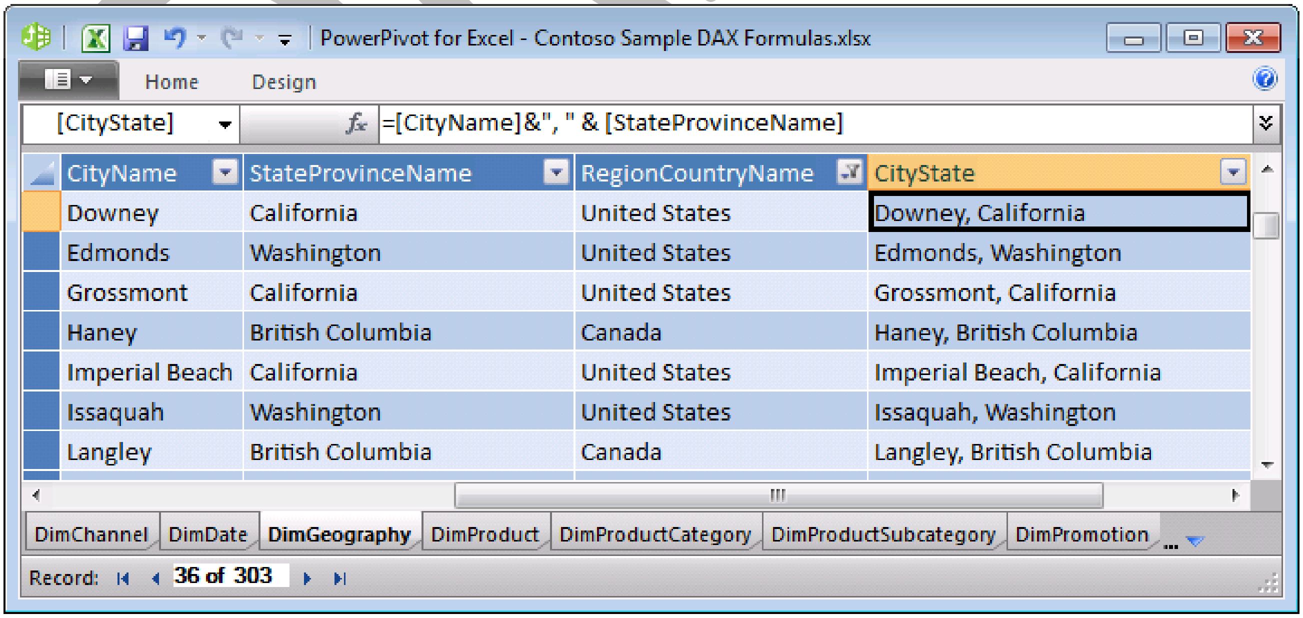


=[SalesAmount]-[TotalCost]

TotalCost	SalesAmount	ETLLoadID	LoadDate	UpdateDate	Margin
$728.40	$1,544.40	1	1/1/2010	1/1/2010	$816.00
$40.60	$78.61	1	1/1/2010	1/1/2010	$38.01
$1,881.27	$3,628.50	1	1/1/2010	1/1/2010	$1,747.23
$1,063.20	$2,254.20	1	1/1/2010	1/1/2010	$1,191.00
$3,468.48	$10,207.08	1	1/1/2010	1/1/2010	$6,738.60

Record: 1 of 3,406,089

2) [CityState]defined as: =[CityName]&", " & [StateProvinceName]



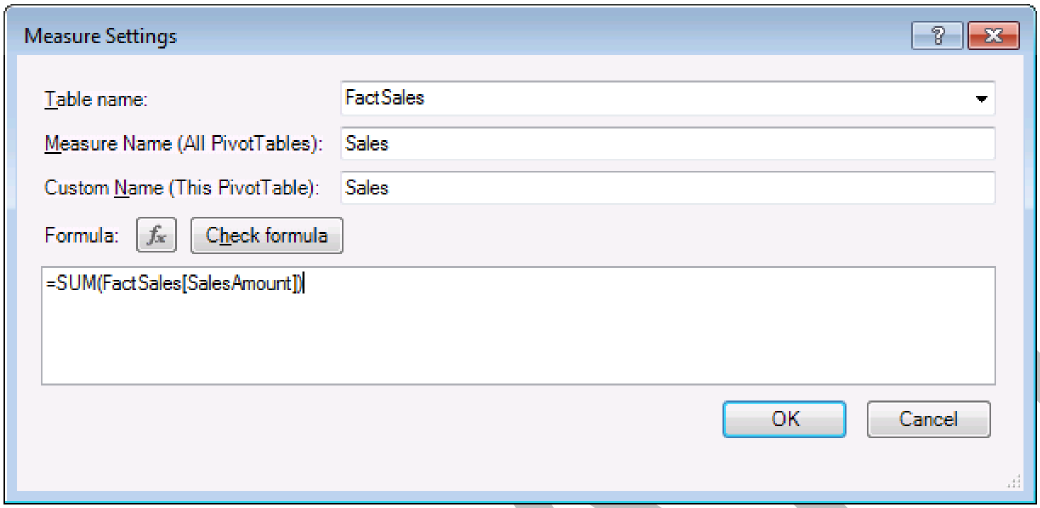
=[CityName]&", " & [StateProvinceName]

CityName	StateProvinceName	RegionCountryName	CityState
Downey	California	United States	Downey, California
Edmonds	Washington	United States	Edmonds, Washington
Grossmont	California	United States	Grossmont, California
Haney	British Columbia	Canada	Haney, British Columbia
Imperial Beach	California	United States	Imperial Beach, California
Issaquah	Washington	United States	Issaquah, Washington
Langley	British Columbia	Canada	Langley, British Columbia

Record: 36 of 303

<u>Measures</u> are named formulas that are defined in the PowerPivot Field List (in the Excel window, while focus is on a PivotTable.) Once defined, they are added to the Values area of the PivotTable. They are defined by providing the measure's name and the measure's formula. The formula is only evaluated when the measure is placed into the Values area of an Excel PivotTable and then it is evaluated separately for each cell in the Values area. Here are a couple of Measure definitions:

- [Sales] defined as: = SUM (FactSales[SalesAmount])



Measure Settings

Table name: FactSales

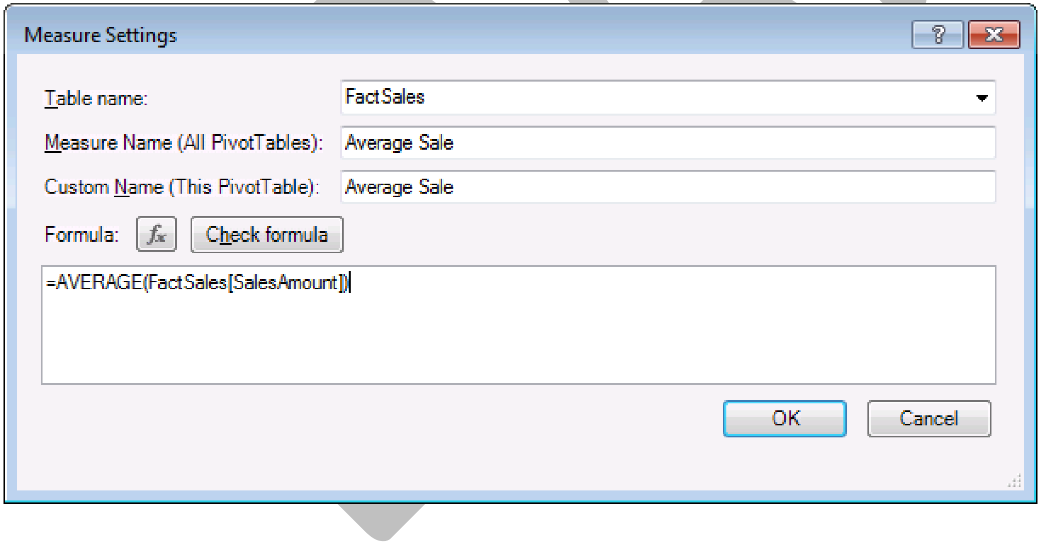
Measure Name (All PivotTables): Sales

Custom Name (This PivotTable): Sales

Formula:

```
=SUM(FactSales[SalesAmount])
```

- [Average Sale] defined as: = AVERAGE (FactSales[SalesAmount])



Measure Settings

Table name: FactSales

Measure Name (All PivotTables): Average Sale

Custom Name (This PivotTable): Average Sale

Formula:

```
=AVERAGE(FactSales[SalesAmount])
```

Here's what you get when you add these two measures to a PivotTable with Calendar Year on Row Labels. Observe how we get four results for each measure – one per year plus a total for all years.

Row Labels	Sales	Average Sale
2007	$4,561,940,955.02	$3,103.94
2008	$4,111,233,534.68	$3,909.73
2009	$3,740,483,119.18	$4,227.38
Grand Total	**$12,413,657,608.89**	**$3,644.55**

In addition to DAX measures that are defined by a DAX formula, PowerPivot also provides a simpler way to define measures when all you want to do is take a column and aggregate it. You can easily build a measure that calculates the SUM, COUNT, MIN, MAX or AVERAGE of a column using checkboxes and dropdowns in the PowerPivot UI. So while it's easy to create a measure that is merely the SUM, COUNT, MIN, MAX, or AVERAGE of a column, you can perform calculations that are far more powerful using DAX formulas instead of the five built in aggregations.

To illustrate this, consider the PivotTable shown below. There are two measures in this PivotTable that show precisely the same results. One (named Sales) uses a DAX formula, (as illustrated above) while the other one (named Sum of Sales Amount) does not.

Row Labels	**Sales**	**Sum of SalesAmount**
Catalog	$1,078,007,547.23	$1,078,007,547.23
Online	$2,677,599,035.07	$2,677,599,035.07
Reseller	$1,715,197,831.44	$1,715,197,831.44
Store	$6,942,853,195.14	$6,942,853,195.14
Grand Total	**$12,413,657,608.89**	**$12,413,657,608.89**

The Measure Settings dialog for the measure "Sum of SalesAmount" shows that this measure was defined by simply checking the SalesAmount column in the field list and leaving the default aggregation as "Sum". This dialog is slightly different than the dialog that appears when a measure is created using a DAX formula.

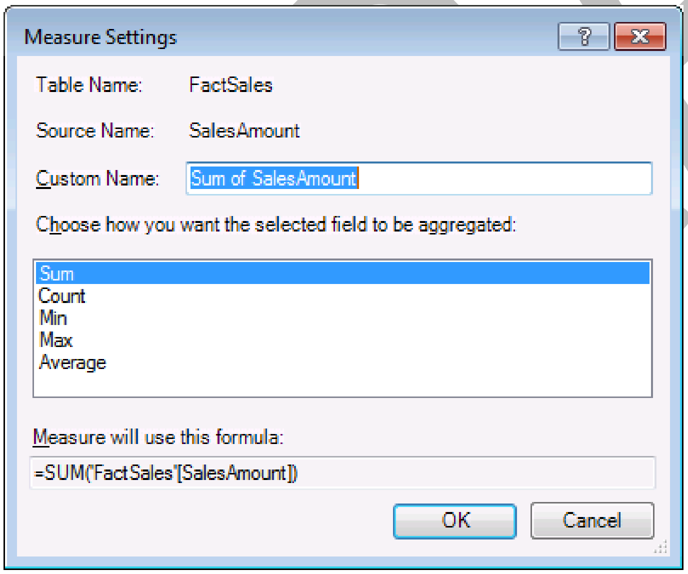


Table Name: FactSales

Source Name: SalesAmount

Custom Name: Sum of SalesAmount

Choose how you want the selected field to be aggregated:

Measure will use this formula:

```
=SUM('FactSales'[SalesAmount])
```

3. DAX Syntax

DAX syntax mimics Excel syntax as much as possible. In particular, DAX uses function composition just as Excel does, and also refers to columns in tables using the same syntax as Excel. DAX then extends that syntax to measures as well.

References to Columns and Measures

The name of a column is always unique within a given table and the name of a measure must be unique across the entire PowerPivot database. Just as each column belongs to a particular table, each measure also belongs to a particular table. We mimic the syntax used by Excel for columns. When a DAX expression refers to a column or measure, the name of that column or measure must be appear within square brackets, and it will sometimes be preceded by the name of the table to which the column or measure belongs. Here are some examples:

Fully qualified names:

- Table1[Column2] as in =SUM(Table1[Column2])
- Table2[Measure1] as in = 2.5 * Table2[Measure1]

Unqualified names

- [Column2] as in =[Column1] + [Column2]
- [Measure2] as in =[Measure2]/[Measure3]

DAX formulas that refer to columns generally require that the references be fully qualified, but an exception is made when a calculated column refers to other columns from within the same table. In these cases, the column references need not be fully qualified. Since measure names are globally unique across a database, we do not generally require measure names to be fully qualified.

Unlike Excel formulas, DAX has no notion of addressing individual cells or ranges. Notation such as B14 or C12:C15 which are valid in Excel will not work in DAX expressions. Instead, DAX always refers to a column of data by providing the (qualified or unqualified) column name. When there is a row context, this reference to a column will be interpreted as the value of that column in the current row.

Note: It is possible to create a calculated column using the same name as a measure from a different table. When this occurs, it is important to use a fully qualified reference to the column in any formula to avoid invoking the measure when the intention was to invoke the calculated column.

4. DAX uses PowerPivot data types

DAX assumes that all values in columns (and the inputs and outputs of all DAX formulas) are one of the following six data types:

Data Type (PowerPivot UI)	Description
Whole Number	Integer
Decimal Number	Double precision real number
Currency	Four decimal places of precision (integer divided by 10,000)

TRUE/FALSE	Boolean
Text	String
Date	Datetime values beginning with Mar 1, 1900

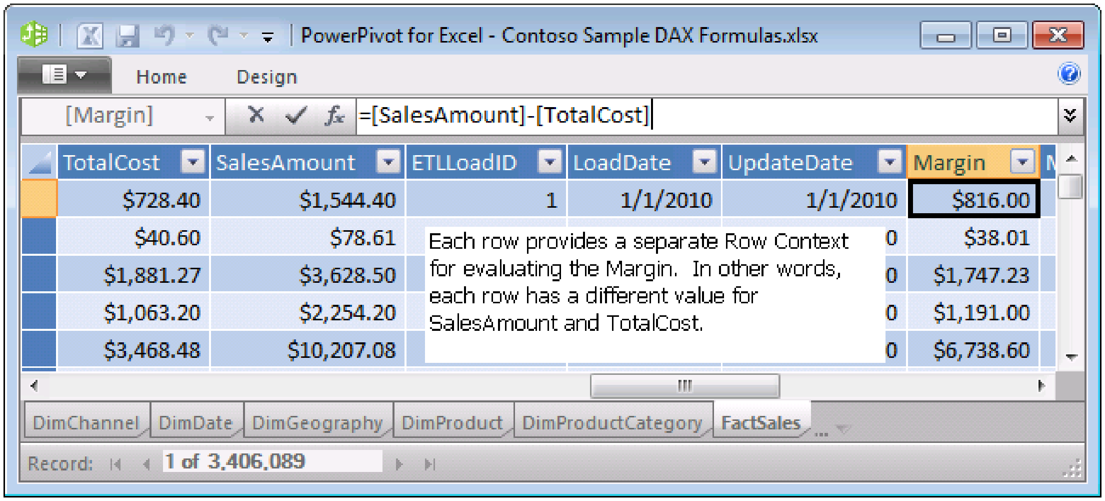
This is slightly different from Excel, where everything is either a number (real) or a string. In Excel data types are handled by formatting numeric values rather than by using different data types. Note that Date values in DAX are restricted to dates after March 1, 1900.

DAX also has functions that return tables of data, but those tables may not be the final value in a measure or calculated column. Tables are used only as intermediate results, and are passed as arguments into additional functions, so that a DAX formula eventually returns a scalar value that has one of the six data types mentioned above.

5. Intro to Context – Row Context and Filter Context

One of the DAX concepts that is important to understand is the concept of the "context" in which each DAX expression is evaluated. This topic will be examined in considerably more detail later in this document (after some DAX functions are described, so that meaningful examples can be shown,) but for now, it's enough to be aware that each formula may be evaluated in the context of a specific row of table data (a "row context") and/or in the context of a specific set of filters (a "filter context"). For example, the formula for a calculated column will be evaluated for each row of a table, using the "row context". Similarly, a measure that's placed into a PivotTable will be evaluated for each cell in the values area, and each of those cells has its own "filter context" which is the combination of the cell's row labels, column labels, report filters, and slicers.

Row Context

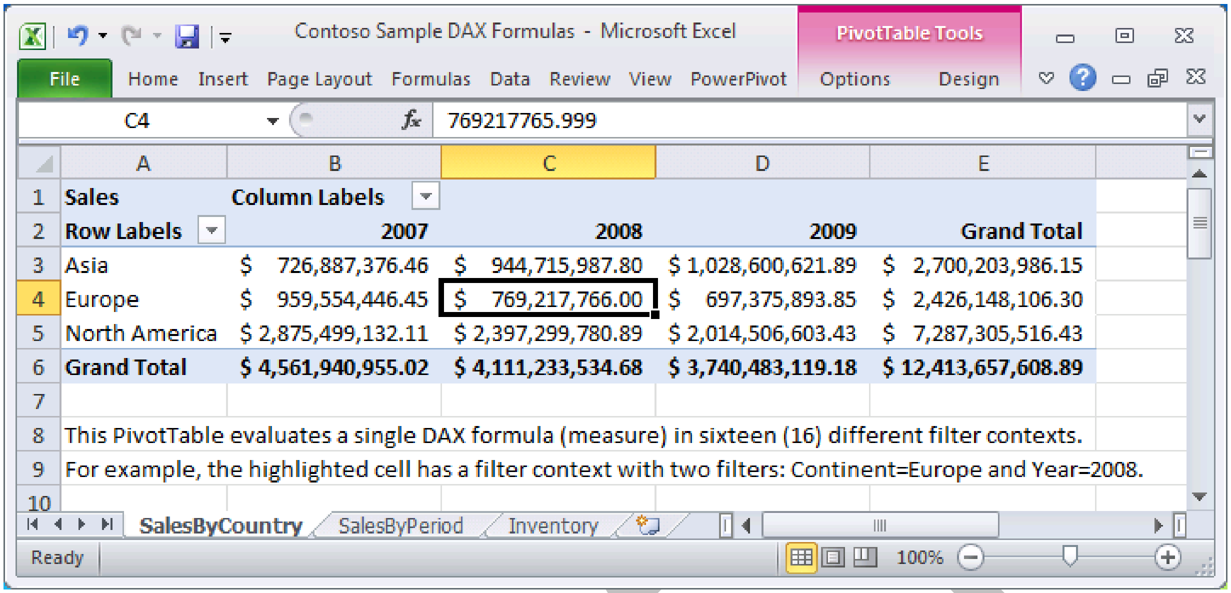


=[SalesAmount]-[TotalCost]

TotalCost	SalesAmount	ETLLoadID	LoadDate	UpdateDate	Margin
$728.40	$1,544.40	1	1/1/2010	1/1/2010	$816.00
$40.60	$78.61			0	$38.01
$1,881.27	$3,628.50			0	$1,747.23
$1,063.20	$2,254.20			0	$1,191.00
$3,468.48	$10,207.08			0	$6,738.60

Each row provides a separate Row Context for evaluating the Margin. In other words, each row has a different value for SalesAmount and TotalCost.

Filter Context



C4 = 769217765.999

	A	B	C	D	E
1	**Sales**	**Column Labels**			
2	**Row Labels**	**2007**	**2008**	**2009**	**Grand Total**
3	Asia	$ 726,887,376.46	$ 944,715,987.80	$ 1,028,600,621.89	$ 2,700,203,986.15
4	Europe	$ 959,554,446.45	$ 769,217,766.00	$ 697,375,893.85	$ 2,426,148,106.30
5	North America	$ 2,875,499,132.11	$ 2,397,299,780.89	$ 2,014,506,603.43	$ 7,287,305,516.43
6	**Grand Total**	**$ 4,561,940,955.02**	**$ 4,111,233,534.68**	**$ 3,740,483,119.18**	**$ 12,413,657,608.89**
7					
8	This PivotTable evaluates a single DAX formula (measure) in sixteen (16) different filter contexts.				
9	For example, the highlighted cell has a filter context with two filters: Continent=Europe and Year=2008.				
10					

6. Functionality that doesn't exist in Excel formulas

PowerPivot includes capabilities (relationships between tables, dynamic aggregation, context modification, etc.) that don't exist within Excel, and therefore we need to have DAX functions that provide functionality that goes beyond the scope of Excel formulas. The details of the DAX functions are described later, but here are some of the categories of DAX functions that don't exist in Excel.

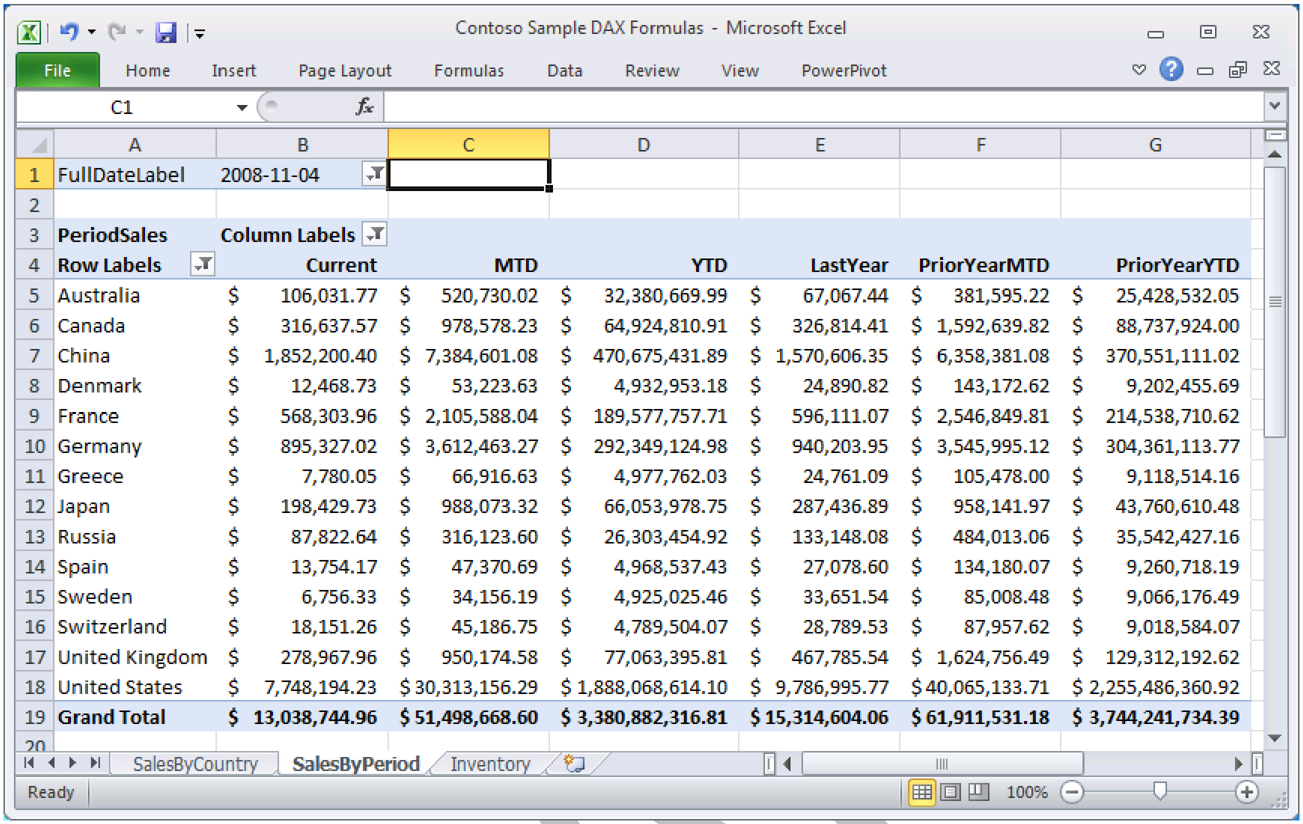
Tables and Relationships require these classes of functions:

- Functions that navigate relationships between tables (more powerful than VLOOKUP)
- Functions that take tables as arguments (aggregation over a table, filtering a table, etc.)
- Functions that produce a table result (this result must then be an input to another function)

Dynamic Measure Aggregation requires these classes of functions:

- Functions that discover the current context for a calculation (e.g. has a specific filter been set?)
- Functions that modify the context for a calculation (e.g. calculate formula for all products or years)
- Functions that know about Time manipulation (e.g. parallel period, previous period, YTD, etc.)

For example, consider this PivotTable showing sales by country for the current period, Month-to-date, Year-to-date, Last Year, PriorYearMTD, and PriorYearYTD. These results are calculated using DAX time intelligence functions as well as DAX aggregation functions.



FullDateLabel	2008-11-04					
PeriodSales	**Column Labels**					
Row Labels	**Current**	**MTD**	**YTD**	**LastYear**	**PriorYearMTD**	**PriorYearYTD**
Australia	$ 106,031.77	$ 520,730.02	$ 32,380,669.99	$ 67,067.44	$ 381,595.22	$ 25,428,532.05
Canada	$ 316,637.57	$ 978,578.23	$ 64,924,810.91	$ 326,814.41	$ 1,592,639.82	$ 88,737,924.00
China	$ 1,852,200.40	$ 7,384,601.08	$ 470,675,431.89	$ 1,570,606.35	$ 6,358,381.08	$ 370,551,111.02
Denmark	$ 12,468.73	$ 53,223.63	$ 4,932,953.18	$ 24,890.82	$ 143,172.62	$ 9,202,455.69
France	$ 568,303.96	$ 2,105,588.04	$ 189,577,757.71	$ 596,111.07	$ 2,546,849.81	$ 214,538,710.62
Germany	$ 895,327.02	$ 3,612,463.27	$ 292,349,124.98	$ 940,203.95	$ 3,545,995.12	$ 304,361,113.77
Greece	$ 7,780.05	$ 66,916.63	$ 4,977,762.03	$ 24,761.09	$ 105,478.00	$ 9,118,514.16
Japan	$ 198,429.73	$ 988,073.32	$ 66,053,978.75	$ 287,436.89	$ 958,141.97	$ 43,760,610.48
Russia	$ 87,822.64	$ 316,123.60	$ 26,303,454.92	$ 133,148.08	$ 484,013.06	$ 35,542,427.16
Spain	$ 13,754.17	$ 47,370.69	$ 4,968,537.43	$ 27,078.60	$ 134,180.07	$ 9,260,718.19
Sweden	$ 6,756.33	$ 34,156.19	$ 4,925,025.46	$ 33,651.54	$ 85,008.48	$ 9,066,176.49
Switzerland	$ 18,151.26	$ 45,186.75	$ 4,789,504.07	$ 28,789.53	$ 87,957.62	$ 9,018,584.07
United Kingdom	$ 278,967.96	$ 950,174.58	$ 77,063,395.81	$ 467,785.54	$ 1,624,756.49	$ 129,312,192.62
United States	$ 7,748,194.23	$ 30,313,156.29	$ 1,888,068,614.10	$ 9,786,995.77	$ 40,065,133.71	$ 2,255,486,360.92
Grand Total	**$ 13,038,744.96**	**$ 51,498,668.60**	**$ 3,380,882,316.81**	**$ 15,314,604.06**	**$ 61,911,531.18**	**$ 3,744,241,734.39**

7. DAX Operators and Constants

DAX supports the usual arithmetic operators (+ - * / ^) for addition, subtraction, multiplication, division, and exponentiation. DAX supports the comparison operators greater than (>), less than (<), greater than or equal to (>=), less than or equal to (<=), equals (=), and not equals (<>). DAX uses the ampersand (&) operator for concatenation. DAX also has logical operators that consist of a double vertical bar (||) for logical OR and double ampersand (&&) for logical AND. DAX does not support the use of "OR" or "AND" as keywords – users should use "||" and "&&" for these operations. DAX also supports TRUE and FALSE as logical constants.

E. Simple DAX Functions

This section focuses on some basic DAX functions that don't require a full understanding of filter context. In subsequent sections of this paper, you will find a more detailed explanation of filter context, followed by a section on the DAX functions that interact with the filter context in various ways.

In addition to the information in this whitepaper, you are encouraged to go to the online Help for PowerPivot for Excel and read the updated help topics for each of the functions discussed in this paper.

- PowerPivot Online Help: PowerPivot for Excel Online Help
- DAX Online Function Reference: DAX Online Function Reference

1. BLANK() and Blank values

When a field in a traditional database does not contain a value, the empty field is often referred to as a NULL value. In Excel, an empty cell is referred to as a "blank" cell. While NULL and BLANK are two closely related concepts, it is useful to consider the difference between them.

In databases that support NULL, all calculations involving NULL will return NULL. For example, NULL+3 generates a NULL result. Trying to perform arithmetic on any NULL will always return a NULL. This is useful in databases where there is a desire to call out the special case of a missing value and to differentiate that missing value from a zero in the data.

In Excel, when you have a BLANK cell in a column of data, Excel allows you to perform arithmetic on the cell and simply treats the blank cell as a zero (or an empty string, depending on the operation being performed.) For example, BLANK +3 generates a result of 3. This makes sense where you are trying to aggregate values and wish to ignore any missing values in the list. This treatment is different than is used by most database products for missing values, which are referred to as NULL, and where NULL +3 generates NULL. Since PowerPivot and DAX follow the Excel logic, we use the term BLANK for missing values rather than NULL.

Note that there is one place where DAX differs from Excel, and this difference is quite intentional. When we have a formula which is adding up a column of numbers, and the entire column contains nothing but blanks, instead of generating a result of zero (which is what Excel does) DAX and PowerPivot will generate a result of BLANK. As long as there are any values in the column being aggregated, we will get a numeric result, but when all the values are BLANK, the result will also be BLANK.

We needed to have this difference in order to properly work in PivotTables. Imagine a database with a couple of thousand cities, and a set of sales that have been filtered to include only eight (8) of those cities. If I build a PivotTable and place [City] on rows, and [Sales] in values, I want to see a PivotTable with only 8 rows. If the sum of blanks was zero (as it is in Excel) then we'd get a PivotTable with two thousand rows and mostly zeroes everywhere. Allowing "empty" data sets to aggregate to BLANK is incredibly useful for PivotTables, since PivotTables automatically (by default) filter away any rows with blank results.

DAX has a function BLANK() that returns an empty (blank) value. This is useful when you want to test to see if the result of an expression is blank, because you can compare the expression to BLANK() . As you will see in the next section DAX also supports the Excel ISBLANK() function for the same purpose.

2. Functions from Excel

DAX supports approximately eighty (80) functions from Excel. There are some specific differences from how these functions work in Excel, but generally these functions are so similar that the learning curve should be very small. The description provided for each of these functions is intentionally brief because these functions are essentially the same as have been shipping in Excel for many years. This document's focus is primarily about functions that are new to DAX, rather than those that are already in Excel.

In places where the Excel function took a range (or a set of ranges,) the DAX function takes a column reference. For example, the function SUM doesn't take a list of ranges in DAX – it takes a column reference and adds up the values in that column.

In places where a function used to return the serial number representing a date, DAX will return the date itself using the date data type.

Logical functions AND and OR only allow for two arguments in DAX. CONCATENATE has the same limitation. To get around this limitation, we recommend using the operators instead of these functions as shown here:

AND	&&
OR	||
CONCATENATE	&

Here are the Excel functions supported in DAX by Category:

Date and Time
DATE
DATEVALUE
DAY
EDATE
EOMONTH
HOUR
MINUTE
MONTH
NOW
SECOND
TIME
TIMEVALUE
TODAY
WEEKDAY
WEEKNUM
YEAR
YEARFRAC

Information
ISBLANK
ISERROR
ISLOGICAL
ISNONTEXT
ISNUMBER
ISTEXT

Logical
AND
IF
IFERROR
NOT
OR
FALSE
TRUE

Math and Trig
ABS
CEILING,
ISO.CEILING
EXP
FACT
FLOOR
INT
LN
LOG
LOG10
MOD
MROUND
PI
POWER
QUOTIENT
RAND
RANDBETWEEN
ROUND
ROUNDDOWN
ROUNDUP
SIGN
SQRT
SUM
SUMSQ
TRUNC

Statistical
AVERAGE
AVERAGEA
COUNT
COUNTA
COUNTBLANK
MAX
MAXA
MIN
MINA

Text
CONCATENATE
EXACT
FIND
FIXED
LEFT
LEN
LOWER
MID
REPLACE
REPT
RIGHT
SEARCH
SUBSTITUTE
TRIM
UPPER
VALUE

3. FORMAT (Value, Format_text)

Instead of Excel's TEXT function, DAX has a FORMAT function for converting various numeric and date values to strings. This function works just like the FORMAT function in Visual Basic.

Start with a field named [TestDate] that is defined as: =DATE (2001, 1, 27) + TIME (17, 4, 23)

In other words, we start with a date field that contains this date and time: Jan 27, 2001 5:04:23 PM. The following examples illustrate how FORMAT can produce different strings from this value:

DAX Formula	Result
=FORMAT([TestDate],"mmmm dd yyyy hh:mm:ss")	January 27 2001 17:04:23
=FORMAT([TestDate],"mmm dd yyyy ddd hh:mm")	Jan 27 2001 Sat 17:04
=FORMAT([TestDate],"dddd mmm-dd")	Saturday Jan-27

4. Functions to aggregate expressions – the "X" functions

DAX implements aggregation functions from Excel including SUM, AVERAGE, MIN, MAX, COUNT, but instead of taking multiple arguments (a list of ranges,) they may take only a reference to a column. This can be somewhat limiting, so DAX also adds some new aggregation functions which aggregate any expression over the rows of a table. Here are the functions:

- SUMX (Table, Expression)
- AVERAGEX (Table, Expression)
- COUNTAX (Table, Expression)
- MINX (Table, Expression)
- MAXX (Table, Expression)

In each case, the first argument is a table over which you want to aggregate an expression, and the second argument is the expression to be aggregated.

Consider this example:

= SUMX (FactSales, [UnitPrice] * [SalesQuantity])

This formula says that we should start with the FactSales table, and for each row of that table we should evaluate the expression [UnitPrice] * [SalesQuantity]. Then the results should all be added up because we're using the SUMX function. If we had used AVERAGEX, we would be taking the average of all the results.

Consider that the following three formulas are precisely identical to each other:

- =SUM (FactSales [SalesQuantity])
- =SUMX (FactSales, [SalesQuantity])
- =SUMX (FactSales, FactSales[SalesQuantity])

The first formula takes the sum of a column, the second formula takes the value from a column for each row of the table and adds them up, and the third formula simply provides a fully qualified name for the column.

These aggregation functions are particularly powerful in measures because the context in which they are evaluated will change (filter) the table over which the aggregation is being performed. For example, if I have a Pivot Table with years in the column labels, and stores in the row labels, and then I place this formula: **= SUMX (FactSales, [UnitPrice] * [SalesQuantity])** into a measure, for each cell of the PivotTable, we'll get the subtotal for the sales belonging to a particular year and store.

When we use functions like this in a measure we are effectively aggregating a table of data across many slices of the data. This is precisely the sort of data analysis for which PowerPivot and PivotTables are designed. A formula like this in a calculated column is far less interesting because the data set isn't being sliced (unless you also use RELATEDTABLE, which is covered next.☺)

5. COUNTROWS (Table)

COUNTROWS is similar to the other COUNT functions (COUNT, COUNTA, COUNTX, COUNTAX, COUNTBLANK) but it takes a table as its argument, and returns the count of rows in that table. For example, the formula =COUNTROWS (FactSales) will return the number of sales transactions in the FactSales table.

6. RELATED (Column) and RELATEDTABLE (Table)

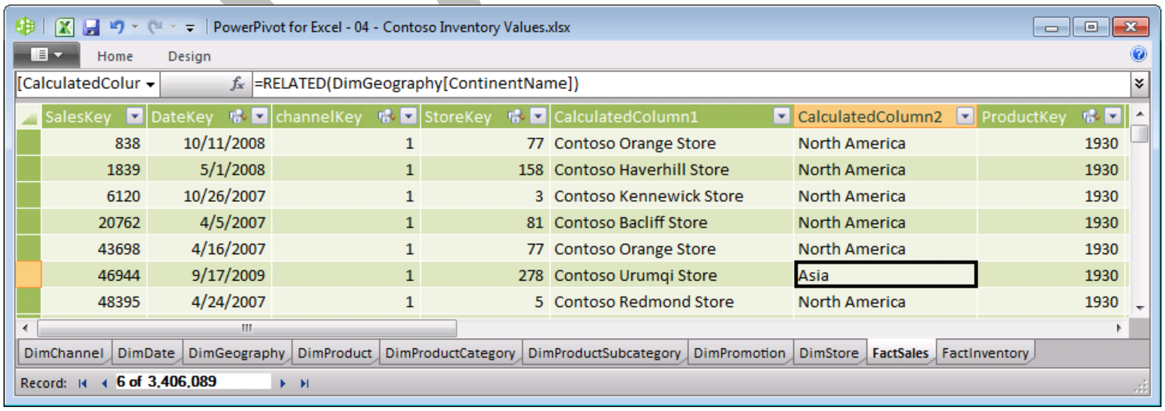
DAX introduces the functions RELATED and RELATEDTABLE for following relationships and retrieving related data from another table. This is more powerful than VLOOKUP in Excel in a couple of ways. First, VLOOKUP only returns the first match – there is no promise of referential integrity and no assurance that there wasn't another row that would also have matched the lookup. Second, instead of requiring the lookup table to be organized in a particular way, with certain columns on the left-hand side, DAX functions rely on relationships between the two tables, and those relationships may involve any of the columns in a table.

RELATED (Column) follows existing many-to-one relationship(s) from the many side to the one side and returns the single matching value from the other table. Consider these examples:

In the FactSales table, let's add two calculated columns using these formulas:

1. =RELATED(DimStore[StoreName])
2. =RELATED(DimGeography[ContinentName])

These formulas will add two columns to the FactSales table, the first containing the name of each store and the second containing the continent name. The first of these examples follows a single relationship from FactSales to DimStore, while the second formula must navigate two relationships: from FactSales to DimStore and then from DimStore to DimGeography. Authoring this formula requires only that you know the name of the column from which you want to pluck a value.



=RELATED(DimGeography[ContinentName])

SalesKey	DateKey	channelKey	StoreKey	CalculatedColumn1	CalculatedColumn2	ProductKey
838	10/11/2008	1	77	Contoso Orange Store	North America	1930
1839	5/1/2008	1	158	Contoso Haverhill Store	North America	1930
6120	10/26/2007	1	3	Contoso Kennewick Store	North America	1930
20762	4/5/2007	1	81	Contoso Bacliff Store	North America	1930
43698	4/16/2007	1	77	Contoso Orange Store	North America	1930
46944	9/17/2009	1	278	Contoso Urumqi Store	Asia	1930
48395	4/24/2007	1	5	Contoso Redmond Store	North America	1930

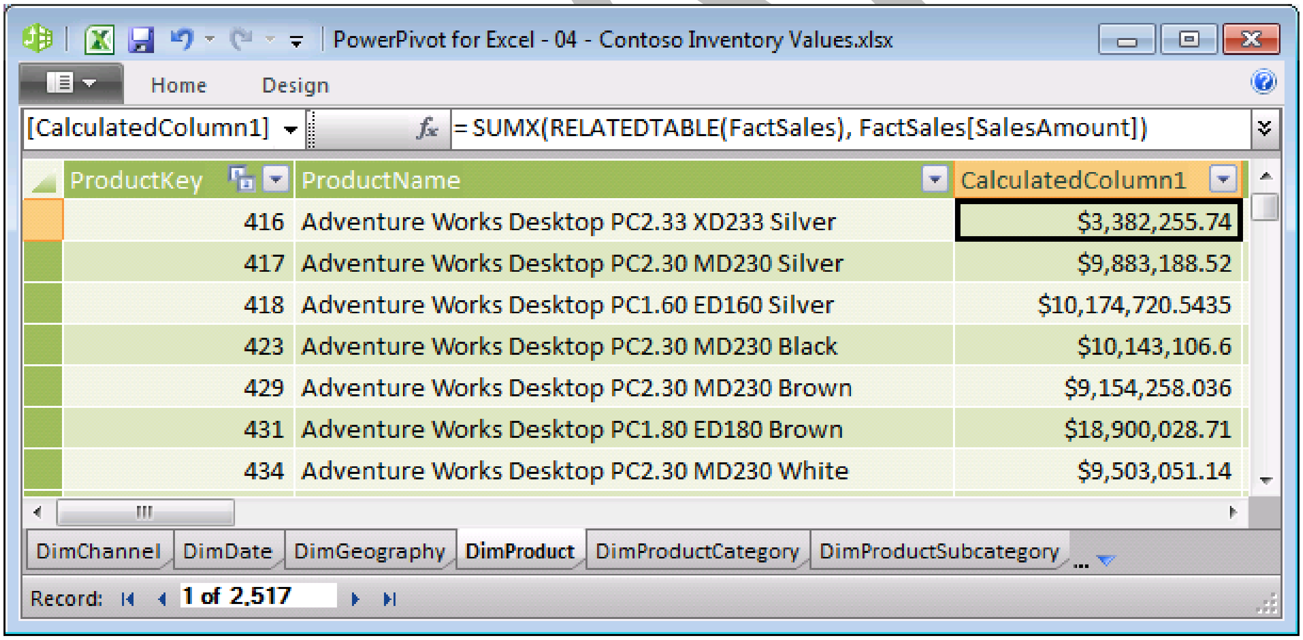
RELATEDTABLE (Table) follows a relationship in either direction (many-to-one or one-to-many) and returns a table containing all the rows that are related to the current row from the specified table. This is very useful when you want to find all the transactions associated with a particular row of a related table.

Note that this function returns a table and not a scalar value. This means that this function cannot be used by itself to define a calculated column or a measure. Instead this function can only be used to provide an intermediate result that is in turn an argument to another function, such an aggregation function.

Consider this example: **= SUMX(RELATEDTABLE(FactSales), FactSales[SalesAmount])**

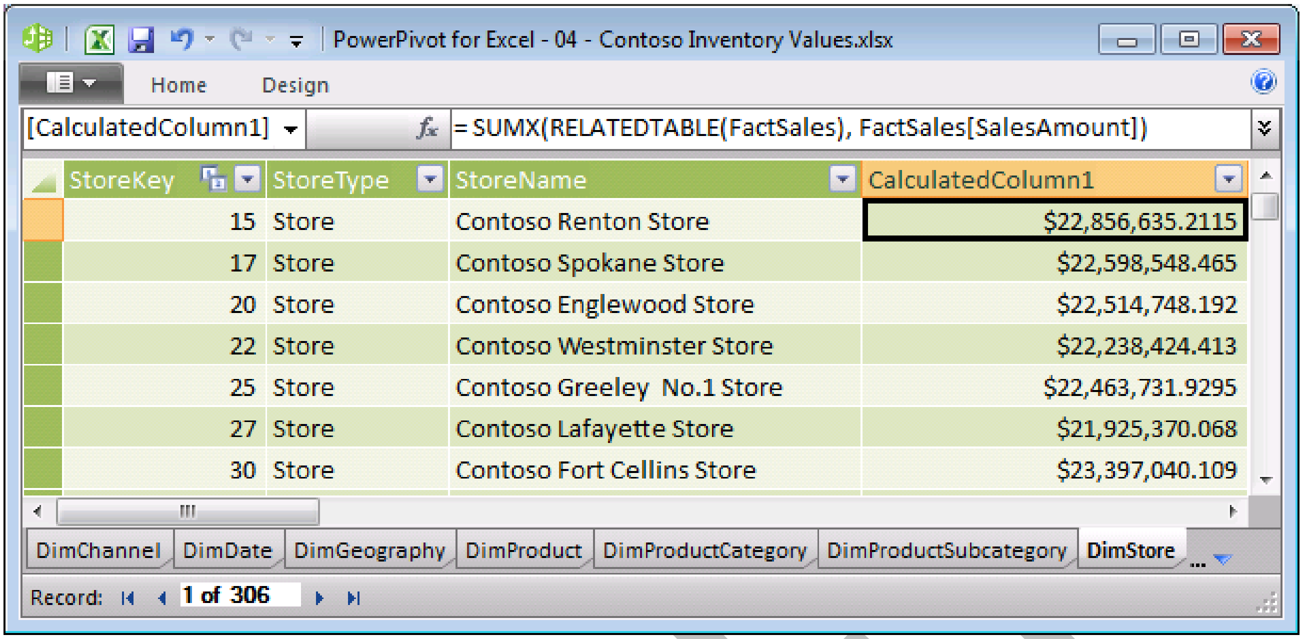
This formula says that we want to first construct a table that contains the rows from FactSales that are related to the current row. RELATEDTABLE(FactSales) assumes that we have a current row and that there is a relationship between the current table and the FactSales table. Once we have the table containing the related rows from the sales transactions, we will then take the Sales Amount from each row, and then add those sales amounts up.

Let's go ahead and place this formula into a calculated column in the DimProduct table. Then let's place the exact same formula with no changes whatsoever into a calculated column in the Dim Store table. Finally we'll place the same formula into the DimDate table. While we get completely different numbers in each of those three tables, we will see that we're getting essentially the same thing: A total of the sales transactions broken down by each product, or by each store, or for each date.



[CalculatedColumn1] = SUMX(RELATEDTABLE(FactSales), FactSales[SalesAmount])

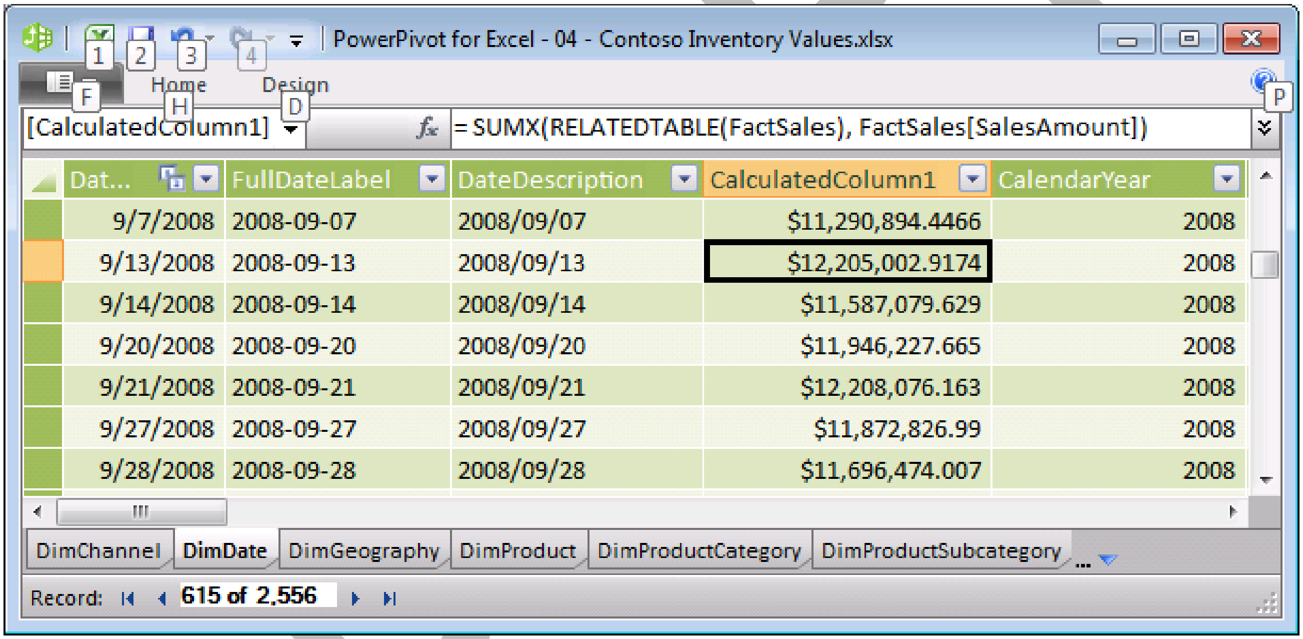
ProductKey	ProductName	CalculatedColumn1
416	Adventure Works Desktop PC2.33 XD233 Silver	$3,382,255.74
417	Adventure Works Desktop PC2.30 MD230 Silver	$9,883,188.52
418	Adventure Works Desktop PC1.60 ED160 Silver	$10,174,720.5435
423	Adventure Works Desktop PC2.30 MD230 Black	$10,143,106.6
429	Adventure Works Desktop PC2.30 MD230 Brown	$9,154,258.036
431	Adventure Works Desktop PC1.80 ED180 Brown	$18,900,028.71
434	Adventure Works Desktop PC2.30 MD230 White	$9,503,051.14



[CalculatedColumn1] = SUMX(RELATEDTABLE(FactSales), FactSales[SalesAmount])

StoreKey	StoreType	StoreName	CalculatedColumn1
15	Store	Contoso Renton Store	$22,856,635.2115
17	Store	Contoso Spokane Store	$22,598,548.465
20	Store	Contoso Englewood Store	$22,514,748.192
22	Store	Contoso Westminster Store	$22,238,424.413
25	Store	Contoso Greeley No.1 Store	$22,463,731.9295
27	Store	Contoso Lafayette Store	$21,925,370.068
30	Store	Contoso Fort Cellins Store	$23,397,040.109

Record: 1 of 306



[CalculatedColumn1] = SUMX(RELATEDTABLE(FactSales), FactSales[SalesAmount])

Dat...	FullDateLabel	DateDescription	CalculatedColumn1	CalendarYear
9/7/2008	2008-09-07	2008/09/07	$11,290,894.4466	2008
9/13/2008	2008-09-13	2008/09/13	$12,205,002.9174	2008
9/14/2008	2008-09-14	2008/09/14	$11,587,079.629	2008
9/20/2008	2008-09-20	2008/09/20	$11,946,227.665	2008
9/21/2008	2008-09-21	2008/09/21	$12,208,076.163	2008
9/27/2008	2008-09-27	2008/09/27	$11,872,826.99	2008
9/28/2008	2008-09-28	2008/09/28	$11,696,474.007	2008

Record: 615 of 2,556

The construct of aggregating across a related table of transactions is very common and provides a powerful way to break down transactions across the rows of a related table.

7. FILTER(Table, Condition) and DISTINCT (Column)

FILTER and DISTINCT are two more DAX functions that return a table of results. Because each of these functions returns a table, they cannot be used as the outermost part of a formula that is placed in a calculated column or measure. Instead these functions will be used as arguments to other functions, typically aggregation functions.

FILTER (Table, Condition) returns a subset of the specified table where the condition is true. It will always return all of the columns of the specified table, and some subset of the rows in that table. For example, the expression FILTER (FactSales,RELATED(DimGeography[CityName])="Baltimore") will return a table containing all the rows from FactSales that took place in the city of Baltimore. To get the sales total for the city of Baltimore, I would simply use this as the table argument to SUMX as follows:

=SUMX(FILTER (FactSales,RELATED(DimGeography[CityName])="Baltimore") , [SalesAmount])

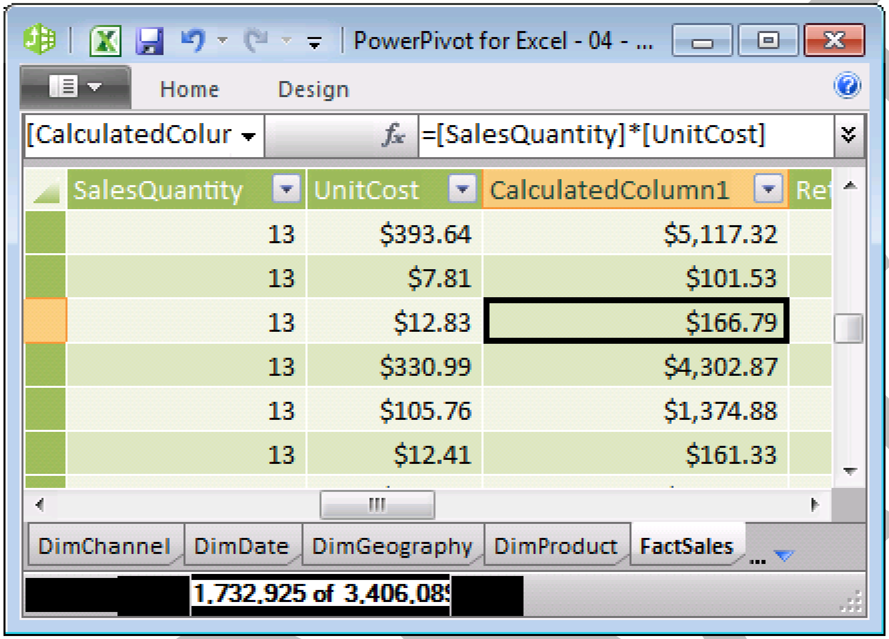
DISTINCT (Column) returns a table containing the unique values within the specified column. In other words, a table of the values, with any duplicate values removed from the list. For example, the expression DISTINCT (FactSales [StoreKey]) will return a table containing the different Store IDs for which there were sales transactions.

F. Row Context and Filter Context

Now that many of the basic DAX functions have been described, let's look at some examples of what we mean by "Row Context" and "Filter Context" because they represent concepts that you need to understand in order to work with some of the more advanced DAX functions such as CALCULATE, described later in this document.

1. Row Context

Row context is most easily thought of as the "current row". This is most obvious in cases where a formula is being entered in a calculated column. For example, within the FactSales table, I can author a formula for a calculated column that looks like this: =[SalesQuantity]*[UnitCost]



=[SalesQuantity]*[UnitCost]

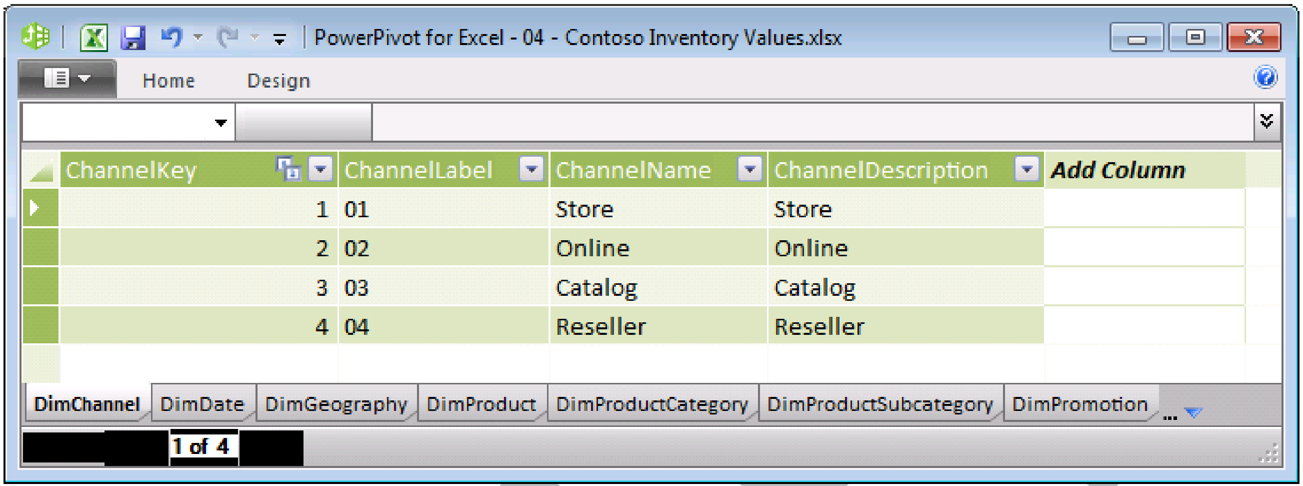
SalesQuantity	UnitCost	CalculatedColumn1	Ret
13	$393.64	$5,117.32	
13	$7.81	$101.53	
13	$12.83	$166.79	
13	$330.99	$4,302.87	
13	$105.76	$1,374.88	
13	$12.41	$161.33	

[redacted] 1,732,925 of 3,406,08 [redacted]

In this scenario, we are taking the values of the [SalesQuantity] and the [UnitCost] columns ***from the current row*** and multiplying the two numbers together. This seems both obvious and intuitive because the same approach works in Excel. But it is important to observe that DAX takes the name of a column ([UnitCost]) and interprets it as a single value ($12.83) when there is a row context. When there is no row context, DAX cannot interpret the name of a column as a value. If I try to enter precisely the same formula in a measure, I will get an error message: **"The value for 'SalesQuantity' cannot be determined. Either 'SalesQuantity' doesn't exist, or there is no current row for a column named 'SalesQuantity'."** In this case, the problem is that there is no current row (or no row context), so there is no way to know what number to use for [SalesQuantity].

Let's consider a different sort of Row Context that's based on scanning a table, rather than filling in values in a calculated column. Whenever a formula has a function that scans a table, that function will inherently apply a row context for each row of the table over which it is scanning. One example of this is the SUMX function. You may recall that SUMX takes two arguments – a table over which to aggregate, and an expression to be evaluated ***for each row in that table***. This means that the expression will be evaluated using a row context for each row of the specified table. For example, I can define a measure as follows: =SUMX(FactSales, [SalesQuantity]*[UnitCost]) and the measure will evaluate the total cost for each transaction (in the context of that row) and then add up the results.

Another way to think about row context is to think of it as a set of filters on a table that result in a single row remaining. For example, consider this table:



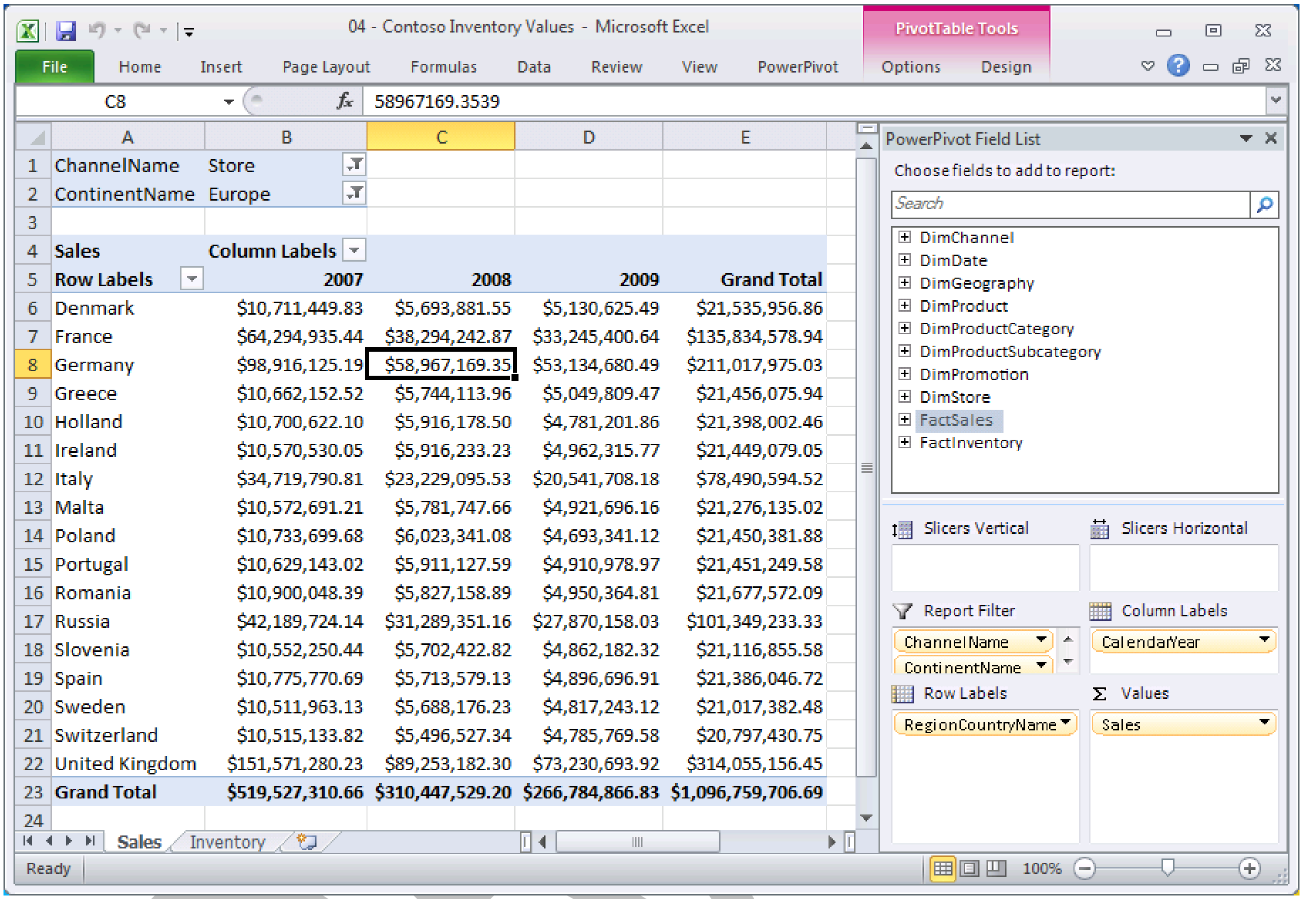
ChannelKey	ChannelLabel	ChannelName	ChannelDescription	Add Column
1	01	Store	Store	
2	02	Online	Online	
3	03	Catalog	Catalog	
4	04	Reseller	Reseller	

[redacted] 1 of 4 [redacted]

The first row of this table is the row where [ChannelKey]=1, [ChannelLabel]="01", [ChannelName]="Store", and [ChannelDescription]="Store". Similarly, the fourth row of this table is the row where [ChannelKey]=4, [ChannelLabel]="04", [ChannelName]="Reseller", and [ChannelDescription]=" Reseller". Thinking about applying the filters of each column in a table to identify a single row is a great way to think of Row Context. Note that in this example, it's enough to filter any one of the columns, but that won't always be the case.

2. Filter Context

Filter Context is more complex than Row Context and can most easily be described as the set of filters associated with one of the cells in the values area of a PivotTable. Consider the following PivotTable:



04 - Contoso Inventory Values - Microsoft Excel

C8 58967169.3539

	A	B	C	D	E
1	ChannelName	Store			
2	ContinentName	Europe			
3					
4	**Sales**	**Column Labels**			
5	**Row Labels**	**2007**	**2008**	**2009**	**Grand Total**
6	Denmark	$10,711,449.83	$5,693,881.55	$5,130,625.49	$21,535,956.86
7	France	$64,294,935.44	$38,294,242.87	$33,245,400.64	$135,834,578.94
8	Germany	$98,916,125.19	$58,967,169.35	$53,134,680.49	$211,017,975.03
9	Greece	$10,662,152.52	$5,744,113.96	$5,049,809.47	$21,456,075.94
10	Holland	$10,700,622.10	$5,916,178.50	$4,781,201.86	$21,398,002.46
11	Ireland	$10,570,530.05	$5,916,233.23	$4,962,315.77	$21,449,079.05
12	Italy	$34,719,790.81	$23,229,095.53	$20,541,708.18	$78,490,594.52
13	Malta	$10,572,691.21	$5,781,747.66	$4,921,696.16	$21,276,135.02
14	Poland	$10,733,699.68	$6,023,341.08	$4,693,341.12	$21,450,381.88
15	Portugal	$10,629,143.02	$5,911,127.59	$4,910,978.97	$21,451,249.58
16	Romania	$10,900,048.39	$5,827,158.89	$4,950,364.81	$21,677,572.09
17	Russia	$42,189,724.14	$31,289,351.16	$27,870,158.03	$101,349,233.33
18	Slovenia	$10,552,250.44	$5,702,422.82	$4,862,182.32	$21,116,855.58
19	Spain	$10,775,770.69	$5,713,579.13	$4,896,696.91	$21,386,046.72
20	Sweden	$10,511,963.13	$5,688,176.23	$4,817,243.12	$21,017,382.48
21	Switzerland	$10,515,133.82	$5,496,527.34	$4,785,769.58	$20,797,430.75
22	United Kingdom	$151,571,280.23	$89,253,182.30	$73,230,693.92	$314,055,156.45
23	**Grand Total**	**$519,527,310.66**	**$310,447,529.20**	**$266,784,866.83**	**$1,096,759,706.69**
24					

PowerPivot Field List

Choose fields to add to report:

Report Filter: ChannelName, ContinentName

Column Labels: CalendarYear

Row Labels: RegionCountryName

Values: Sales

This PivotTable has only one measure, with a single DAX formula defined as **=SUM(FactSales[SalesAmount])** That single formula is being evaluated 72 distinct times, with 72 different results, and each of those 72 results has a distinct ***Filter Context***. The context for each cell in the Values area includes the items on the row labels, the column labels, the report filter, (and slicers if they were being used.) The cell that is highlighted above has the following ***Filter Context***.

- [RegionCountryName] = "Germany"
- [CalendarYear] = 2008
- [ChannelName]="Store"
- [ContinentName]="Europe"

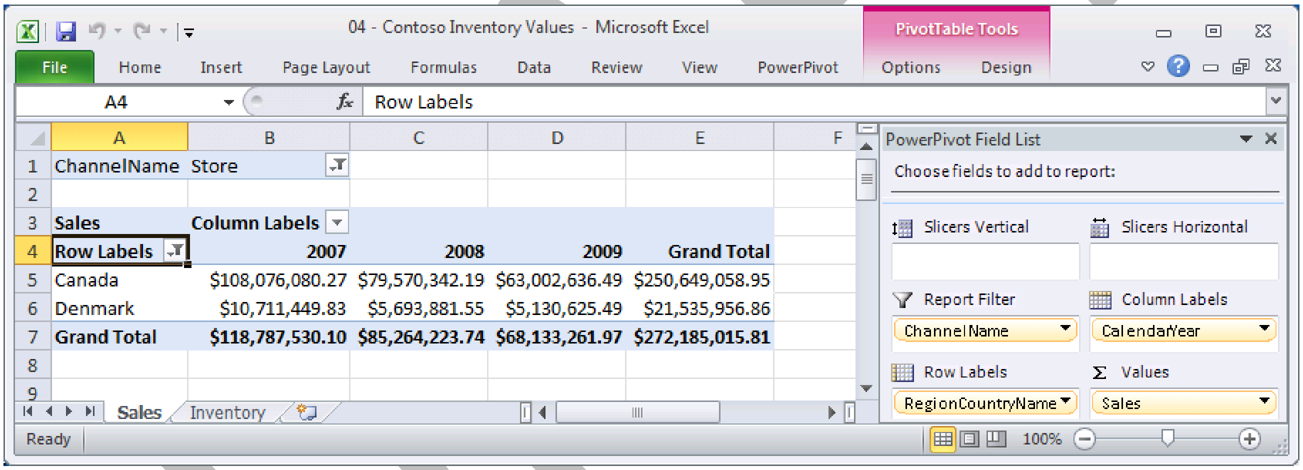
This can be thought of as applying four filters to the FactSales table prior to evaluating the formula which is simply the sum of the [SalesAmount] values for the rows that are left after applying those four filters. This is where the name "Filter Context" comes from.

3. Relationships and Filter Context

When there is a relationship between two tables in PowerPivot, that relationship is always considered a "many-to-one" relationship that goes from the table containing "many" records for each instance of the key to the table containing "one" record for each instance of the key. For example, there is a many-to-one relationship from the table FactSales to the table DimProducts, with many rows for each product in FactSales, and only one row for each product in DimProducts.

It turns out that applying a filter to a table on the "one" side of the relationship will also cause the table on the "many" side of the relationship to be filtered. For example, if I filter DimProducts so that only one product remains, then FactSales will also be filtered so that it only contains the sales transactions for that one product. Applying a filter to the table on the "many" side of a relationship (filter FactSales to include only certain products) will not have any impact on the table on the "one" side of the relationship.

This is how PivotTables are designed to work, and if you look at some examples, it makes perfect sense. Consider the PivotTable below where DimGeography has been filtered to include only two countries. It's quite natural that FactSales is constrained by the same filter, even though [RegionCountryName] isn't a field in the FactSales table. It's a field in a table that is on the "one" side of a relationship to FactSales.



	A	B	C	D	E
1	ChannelName	Store			
2					
3	Sales	Column Labels			
4	Row Labels	2007	2008	2009	Grand Total
5	Canada	$108,076,080.27	$79,570,342.19	$63,002,636.49	$250,649,058.95
6	Denmark	$10,711,449.83	$5,693,881.55	$5,130,625.49	$21,535,956.86
7	Grand Total	$118,787,530.10	$85,264,223.74	$68,133,261.97	$272,185,015.81

Report Filter: ChannelName
Column Labels: CalendarYear
Row Labels: RegionCountryName
Values: Sales

4. Measures and Filter Context

The formula that defines a measure is always evaluated multiple times – once for each cell in the Values area. And each of those evaluations has its own filter context. Even the grand total in the PivotTable above for all countries and for all years is evaluated in its own context, namely the context where [RegionCountryName] = ALL, [CalendarYear]=ALL, and [ChannelName]="Store".

The presence of filter context for all measure evaluations (and the presence of row context for calculated columns,) is one of the reasons why you often cannot use the same formula to define a measure as you would use to define a calculated column. Generally, because a measure must be evaluated many times, including for any totals rows or columns, measure formulas must do some sort of aggregation. Most measure formulas will either be the aggregation (Sum, Count, Average, Min, or Max) of an expression, or a formula involving other measures, or some combination of the two.

G. More DAX Functions

1. CALCULATE(Expression, SetFilter1, SetFilter2,...)

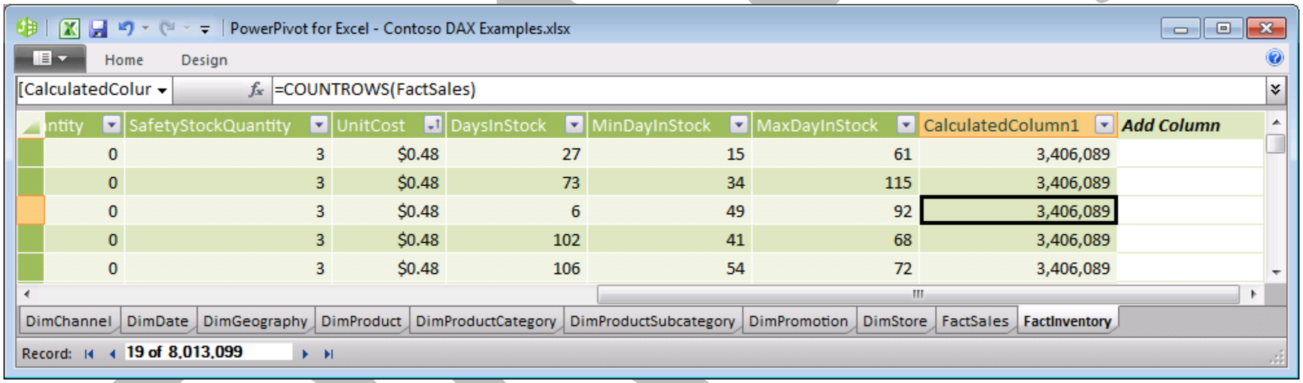
The CALCULATE function is very powerful and very useful, but is conceptually a bit more difficult than any of the DAX functions described up to this point. CALCULATE allows any DAX expression to be evaluated in a specified filter context. This is equivalent to defining a measure and also defining a set of filters that will be used to provide a context in which the measure is to be evaluated. CALCULATE does the following:

1. Using the SetFilter arguments, modify the Filter Context
2. If there is a Row Context, move that Row Context onto the Filter Context
3. Evaluate the Expression in the newly modified Filter Context

Here are some examples that illustrate how this works.

Example1 – CALCULATE without any SetFilter arguments

Using our sample data from the Contoso database, let's start by adding a calculated column to the FactInventory table with this formula: = COUNTROWS (FactSales)

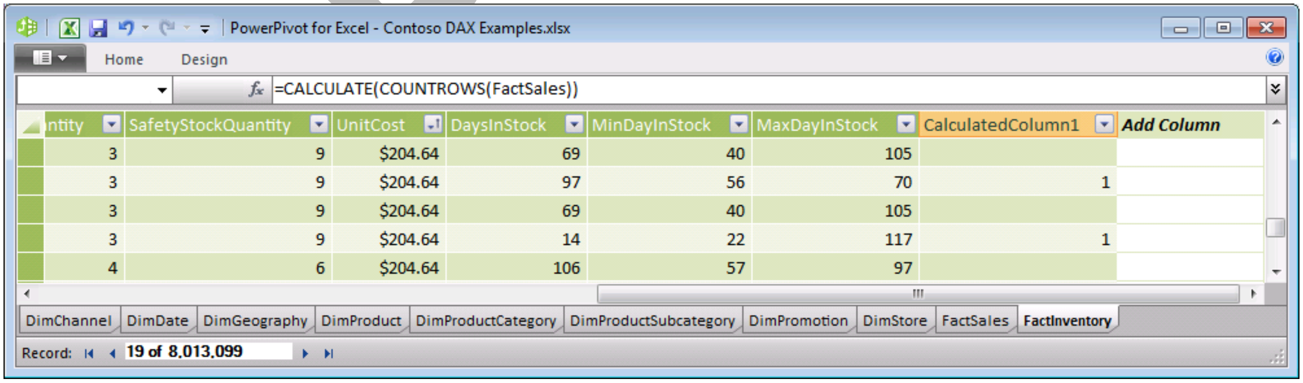


=COUNTROWS(FactSales)

ntity	SafetyStockQuantity	UnitCost	DaysInStock	MinDayInStock	MaxDayInStock	CalculatedColumn1	Add Column
0	3	$0.48	27	15	61	3,406,089	
0	3	$0.48	73	34	115	3,406,089	
0	3	$0.48	6	49	92	3,406,089	
0	3	$0.48	102	41	68	3,406,089	
0	3	$0.48	106	54	72	3,406,089	

We should not be surprised when we get the number of rows (approx 3.4 million) in the FactSales table, and we get the same result for every cell in the new calculated column.

Now let's change the formula to this: =CALCULATE(COUNTROWS(FactSales)). Observe that we get two different values in the calculated column, either a blank or the value 1. Why did this happen?



=CALCULATE(COUNTROWS(FactSales))

ntity	SafetyStockQuantity	UnitCost	DaysInStock	MinDayInStock	MaxDayInStock	CalculatedColumn1	Add Column
3	9	$204.64	69	40	105		
3	9	$204.64	97	56	70	1	
3	9	$204.64	69	40	105		
3	9	$204.64	14	22	117	1	
4	6	$204.64	106	57	97		

First, CALCULATE caused the current Row Context to be placed onto the Filter Context. This means that the filter context got a set of filters that look like this:

- [InventoryKey] = <value in this row>
- [DateKey] = <value in this row>
- [StoreKey] = <value in this row>
- [ProductKey]= = <value in this row>
- [CurrencyKey] = <value in this row>
- [OnHandQuantity] = <value in this row>
- [OnOrderQuantity] = <value in this row>
- Etc.... for every field in the FactInventory table (every field in the Row Context)

What makes this a bit more complicated, is that the RowContext is not merely the current row from that table, but actually the current row from that table as well as the current row from all tables on the one side of a many-to-one relationship from that table. Until now, it’s been simpler to think of the RowContext as being from a single table, but it actually includes the current row from the entire set of related tables. This means that the RowContext is the current row from FactInventory, as well as the current row from DimDate, the current row from DimProduct, and the current row from DimStore. This means that the filter context also got a set of filters that look like this:

- [DateKey] = <value in the related row in DimDate>
- [FullDateLabel] = <value in the related row in DimDate>
- Etc.... for every field in the DimDate table
- [ProductKey]= <value in related row in DimProduct>
- [ProductLabel]= <value in related row in DimProduct>
- Etc.... for every field in the DimProduct table
- [StoreKey] = <value in related row in DimStore>
- [StoreType] = <value in related row in DimStore>
- Etc.... for every field in the DimStore table

Now, using that modified filter context, we want to count the rows in the FactSales table using the modified filter context. This is just like performing a calculation for a measure in a PivotTable where all of these filters have been placed on the PivotTable. Note that many of the fields above do not have any impact on the FactSales table, but some of them do. The filters from the DimDate, DimStore, and DimProduct tables are all fields for which there is a relationship to FactSales, so this filter context has effectively filtered the FactSales table down to the rows that have a specific date, store, and product. It turns out that with this data set, the filtered FactSales table has either no rows, or a single row. Therefore the formula results in a value of BLANK or 1 depending on the values in the FactInventory row.

Example2 – SetFilter arguments

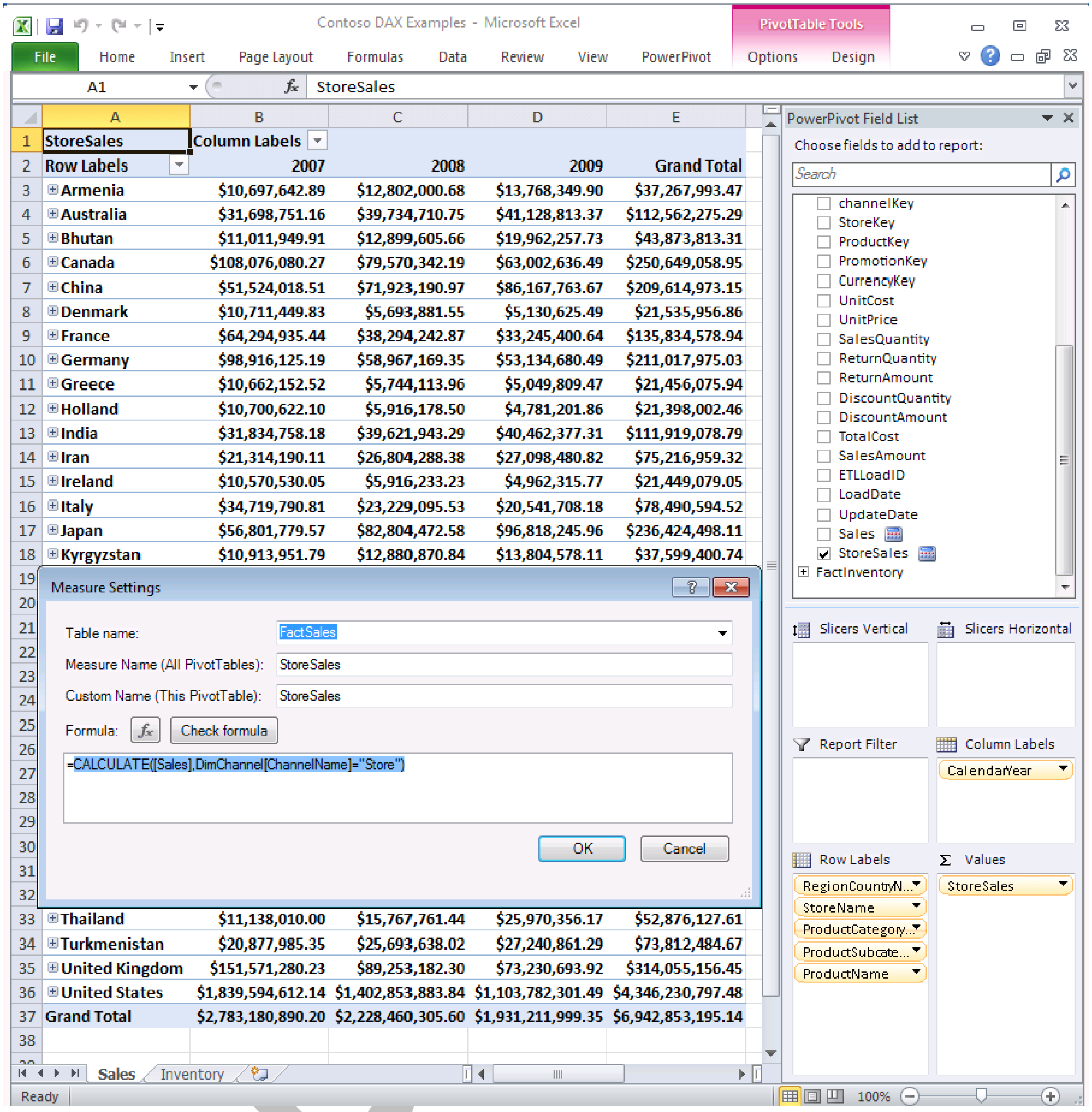
The SetFilter argument is used to modify the context in which an expression is going to be evaluated.

Let’s say that we want to do some analysis on sales data. Let’s define a simple measure on the FactSales table named [Sales] that is defined by this DAX formula: =SUM(FactSales[SalesAmount]). [Sales] is nothing more than the sum of the [SalesAmount] field for all the sales transactions contained in any particular slice of the data. But there’s a twist because the Contoso sales data includes sales made via four distinct channels: There are “Catalog” sales, “Online” sales, “Reseller” sales, and “Store” sales. Each of these is a separate row in the DimChannel table, and every FactSales row is identified as belonging to one of these channels by the [ChannelKey] field in that table. (There is of course a many-to-one relationship from FactSales to DimChannel.)

Suppose that the sales analysis I want to perform is to be based on Store Sales worldwide. I expect various people in my department to slice the sales data a variety of ways – by country, by time, by store, by product, and by any of the fields available in the database. But I want to make sure that no matter what they choose, they are only looking at sales in the “Store” channel. If I don’t do anything special, I run the risk that the analysis will inadvertently combine store sales with other kinds of sales, because they might forget to place a Channel filter on their PivotTable.

Note that this would be an easy mistake to make because the sales data for Contoso includes Store sales in 34 countries. In 30 of those countries, Store sales is all there is. In this data set, Catalog sales are limited to the United States, Online sales are limited to three countries (US, Germany, China), and Reseller sales are also limited to three countries (US, France, China). Someone who is analyzing sales in Canada would not see any difference between Store Sales and Sales for all channels, but someone analyzing data for the US or China would see a dramatic difference.

To force the values to be from the “Store” channel, I will define a new measure named [StoreSales] which is defined as: = CALCULATE ([Sales], DimChannel [ChannelName]=”Store”). The SetFilter argument within CALCULATE says that we should override any filter (if any) on the Channel Name column with a new filter that says we only want sales in the Store channel. By using this measure, we are guaranteed to be looking at Store sales, and we don’t have to rely on PivotTable authors to place the Channel somewhere on their PivotTable.



fx StoreSales

	A	B	C	D	E
1	StoreSales	Column Labels			
2	Row Labels	2007	2008	2009	Grand Total
3	⊞Armenia	$10,697,642.89	$12,802,000.68	$13,768,349.90	$37,267,993.47
4	⊞Australia	$31,698,751.16	$39,734,710.75	$41,128,813.37	$112,562,275.29
5	⊞Bhutan	$11,011,949.91	$12,899,605.66	$19,962,257.73	$43,873,813.31
6	⊞Canada	$108,076,080.27	$79,570,342.19	$63,002,636.49	$250,649,058.95
7	⊞China	$51,524,018.51	$71,923,190.97	$86,167,763.67	$209,614,973.15
8	⊞Denmark	$10,711,449.83	$5,693,881.55	$5,130,625.49	$21,535,956.86
9	⊞France	$64,294,935.44	$38,294,242.87	$33,245,400.64	$135,834,578.94
10	⊞Germany	$98,916,125.19	$58,967,169.35	$53,134,680.49	$211,017,975.03
11	⊞Greece	$10,662,152.52	$5,744,113.96	$5,049,809.47	$21,456,075.94
12	⊞Holland	$10,700,622.10	$5,916,178.50	$4,781,201.86	$21,398,002.46
13	⊞India	$31,834,758.18	$39,621,943.29	$40,462,377.31	$111,919,078.79
14	⊞Iran	$21,314,190.11	$26,804,288.38	$27,098,480.82	$75,216,959.32
15	⊞Ireland	$10,570,530.05	$5,916,233.23	$4,962,315.77	$21,449,079.05
16	⊞Italy	$34,719,790.81	$23,229,095.53	$20,541,708.18	$78,490,594.52
17	⊞Japan	$56,801,779.57	$82,804,472.58	$96,818,245.96	$236,424,498.11
18	⊞Kyrgyzstan	$10,913,951.79	$12,880,870.84	$13,804,578.11	$37,599,400.74
33	⊞Thailand	$11,138,010.00	$15,767,761.44	$25,970,356.17	$52,876,127.61
34	⊞Turkmenistan	$20,877,985.35	$25,693,638.02	$27,240,861.29	$73,812,484.67
35	⊞United Kingdom	$151,571,280.23	$89,253,182.30	$73,230,693.92	$314,055,156.45
36	⊞United States	$1,839,594,612.14	$1,402,853,883.84	$1,103,782,301.49	$4,346,230,797.48
37	Grand Total	$2,783,180,890.20	$2,228,460,305.60	$1,931,211,999.35	$6,942,853,195.14

Measure Settings

Table name: FactSales

Measure Name (All PivotTables): StoreSales

Custom Name (This PivotTable): StoreSales

Formula: *fx* Check formula

```
=CALCULATE([Sales],DimChannel[ChannelName]="Store")
```

OK Cancel

PowerPivot Field List

Choose fields to add to report:

Search

- ☐ channelKey
- ☐ StoreKey
- ☐ ProductKey
- ☐ PromotionKey
- ☐ CurrencyKey
- ☐ UnitCost
- ☐ UnitPrice
- ☐ SalesQuantity
- ☐ ReturnQuantity
- ☐ ReturnAmount
- ☐ DiscountQuantity
- ☐ DiscountAmount
- ☐ TotalCost
- ☐ SalesAmount
- ☐ ETLLoadID
- ☐ LoadDate
- ☐ UpdateDate
- ☐ Sales
- ☑ StoreSales
- ⊞ FactInventory

Slicers Vertical | Slicers Horizontal

Report Filter

Column Labels: CalendarYear

Row Labels: RegionCountryN..., StoreName, ProductCategory..., ProductSubcate..., ProductName

Σ Values: StoreSales

Syntax Shortcut for CALCULATE (expression [,SetFilter1] [,SetFilter2]...)

When you have a CALCULATE function where the expression to be evaluated is simply a measure, then there is a convenient shortcut available. Let’s consider the example above.

= CALCULATE ([Sales], DimChannel [ChannelName]=”Store”)

In order to make certain common cases easier to author and easier to read, we offer the following shortcut:

When the expression to be evaluated is a measure, a shortcut for CALCULATE (<measure>, <optional SetFilters>) is to use the name of the measure as if it were a function name and write this instead:

= <MeasureName> (<optional SetFilters>)

When we apply this to our example, we find that StoreSales can be defined as

= [Sales](DimChannel [ChannelName]=”Store”)

This is easier to read and author and I’ll use this notation in several places going forward in this paper.

Note: There are known issues with auto-complete for formulas that use the shortcut syntax.

More info about SetFilter arguments

A SetFilter argument in CALCULATE may be either of the following:

1. A Boolean expression that refers to a single column such as ***DimChannel [ChannelName] =”Store”*** or ***(DimGeography[CityName]=”Seattle” || DimGeography[CityName]=”Portland”)***. Note that the Boolean expression may not refer to measures and may not invoke the Calculate function nor any table scanning functions including aggregation functions or table valued functions.

2. A table expression such as ***Filter(Table1, Condition)***
   Let’s consider how a Table SetFilter should be interpreted. Consider a table which contains three columns named “City”, “Product”, and “Month”. The rows in the table specify the valid combinations of values for those columns. Any combination of values not present in the table is filtered away. In other words, we can pass a table like this as a SetFilter argument to the CALCULATE function, and it will filter away any combinations of city, product, and month that aren’t in this table.

[City]	[Product]	[Month]
Seattle	Bike	Jan 2008
Seattle	Car	Feb 2008
Boston	Bike	Mar 2008

   The most common scenario for using a Table as a SetFilter argument to the Calculate function is the ALL function which will be illustrated later in this document.

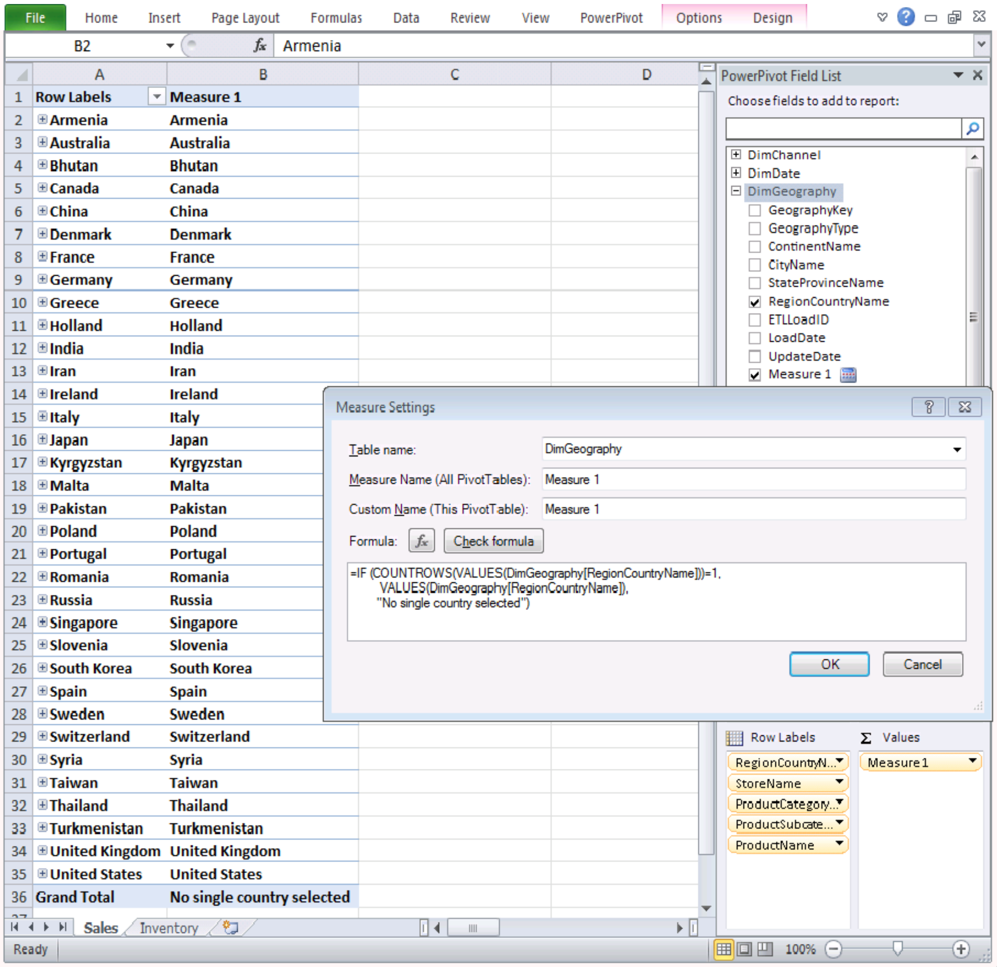
2. VALUES(column)

The VALUES function will return all the valid values for that column in the current filter context. The result comes back as a table of values, even though the table may have only one value (or even no values). This function is an easy way to ask about the current filter context. This function will often be used within an IF function. Imagine a scenario where you want to do one calculation when the country is the United States, and a different calculation when the country is not the United States. This can be accomplished by testing to see if VALUES(DimGeography[RegionCountryName]) = “United States”. Of course there might be a PivotTable where the country isn’t specified, or a situation where multiple countries have been selected and we can only compare a table to a single value when the table has only one value. This forces us to write something like this to determine what the current country is:

```
= IF (COUNTROWS(VALUES(DimGeography[RegionCountryName]))=1,
     VALUES(DimGeography[RegionCountryName]),
```

"No single country selected")

This formula says that if there is only one country selected in the current context, return the name of that country, else return the expression “No single country selected”.   The result of placing this measure in a PivotTable where the country is on Row Labels looks like this:



Row Labels	Measure 1
Armenia	Armenia
Australia	Australia
Bhutan	Bhutan
Canada	Canada
China	China
Denmark	Denmark
France	France
Germany	Germany
Greece	Greece
Holland	Holland
India	India
Iran	Iran
Ireland	Ireland
Italy	Italy
Japan	Japan
Kyrgyzstan	Kyrgyzstan
Malta	Malta
Pakistan	Pakistan
Poland	Poland
Portugal	Portugal
Romania	Romania
Russia	Russia
Singapore	Singapore
Slovenia	Slovenia
South Korea	South Korea
Spain	Spain
Sweden	Sweden
Switzerland	Switzerland
Syria	Syria
Taiwan	Taiwan
Thailand	Thailand
Turkmenistan	Turkmenistan
United Kingdom	United Kingdom
United States	United States
Grand Total	No single country selected

PowerPivot Field List

Choose fields to add to report:

- DimChannel
- DimDate
- DimGeography
  - □ GeographyKey
  - □ GeographyType
  - □ ContinentName
  - □ CityName
  - □ StateProvinceName
  - ☑ RegionCountryName
  - □ ETLLoadID
  - □ LoadDate
  - □ UpdateDate
  - ☑ Measure 1

Row Labels: RegionCountryN..., StoreName, ProductCategory..., ProductSubcate..., ProductName

Values: Measure 1

Measure Settings

Table name: DimGeography

Measure Name (All PivotTables): Measure 1

Custom Name (This PivotTable): Measure 1

Formula:

```
=IF (COUNTROWS(VALUES(DimGeography[RegionCountryName]))=1,
     VALUES(DimGeography[RegionCountryName]),
     "No single country selected")
```

3. CALCULATETABLE(TableExpression, SetFilter1, SetFilter2,...)

CALCULATETABLE is just like CALCULATE, except that the expression and the result are both tables. This would be used when you want to change the filter context and then construct a table in that new context.

4. ALL(Table) and ALL(Column1 [,Column2]...)

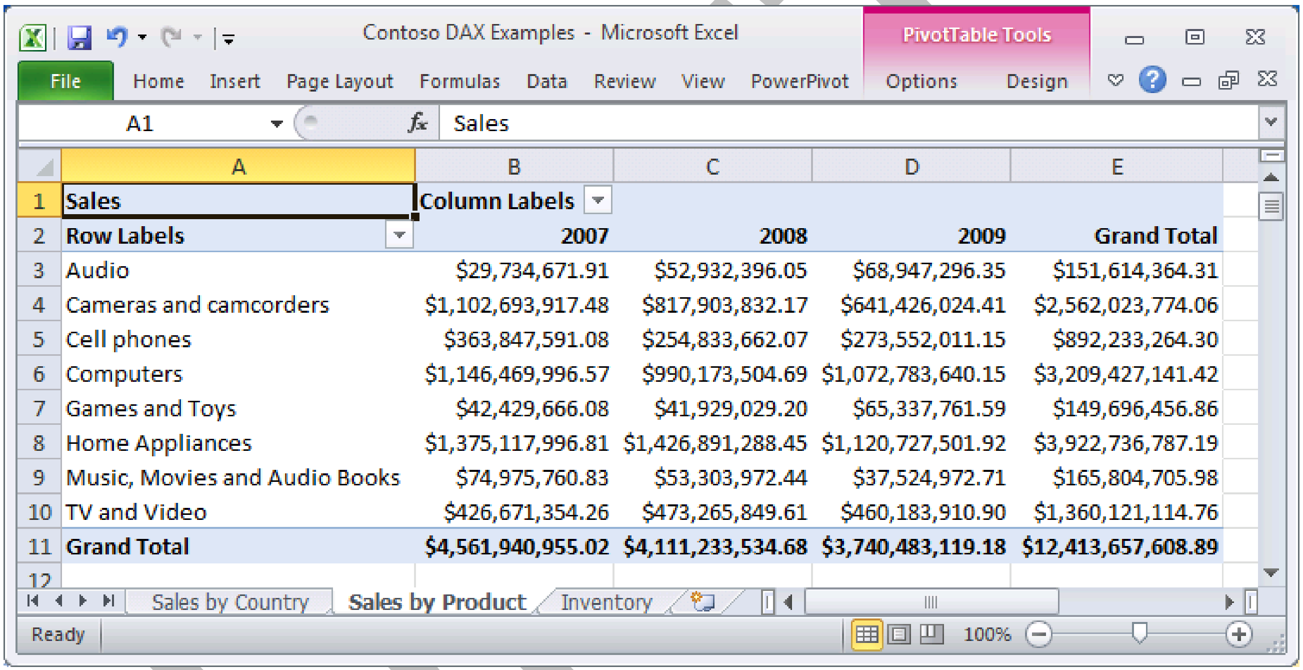
The ALL function is a table valued function that that causes the filter context for the specified columns to be ignored. This function is particularly useful when used as a table valued SetFilter argument within the CALCULATE function. Consider some examples:

ALL (DimProduct) returns a table containing all the rows within DimProduct, ignoring any filters that may be present in the filter context. Duplicate rows will be removed. Because the argument to ALL is a table, the filter context is effectively removed from all columns in that table.

ALL (column1) returns a table containing all the values from column1 (without any duplicates) after removing/ignoring any filters from the filter context that may have been present on that column.

When multiple column arguments are supplied to the ALL function, it is required that all of those columns belong to the same table. For example, ALL (column1, column2) returns a table with two columns from a source table, consisting of all the combinations of column1 and column2 that were present in the original data removing/ignoring any filters from the filter context that may have been present on those columns.

Consider the measure FactSales[Sales] that has been defined as =SUM(FactSales[SalesAmount]). By itself, the measure [Sales] is the sum of the Sales Amount column for whatever the current context may be. Looking at the PivotTable below, you see that this is a different number in each cell of the PivotTable because each cell has a different context (a different product category and year).

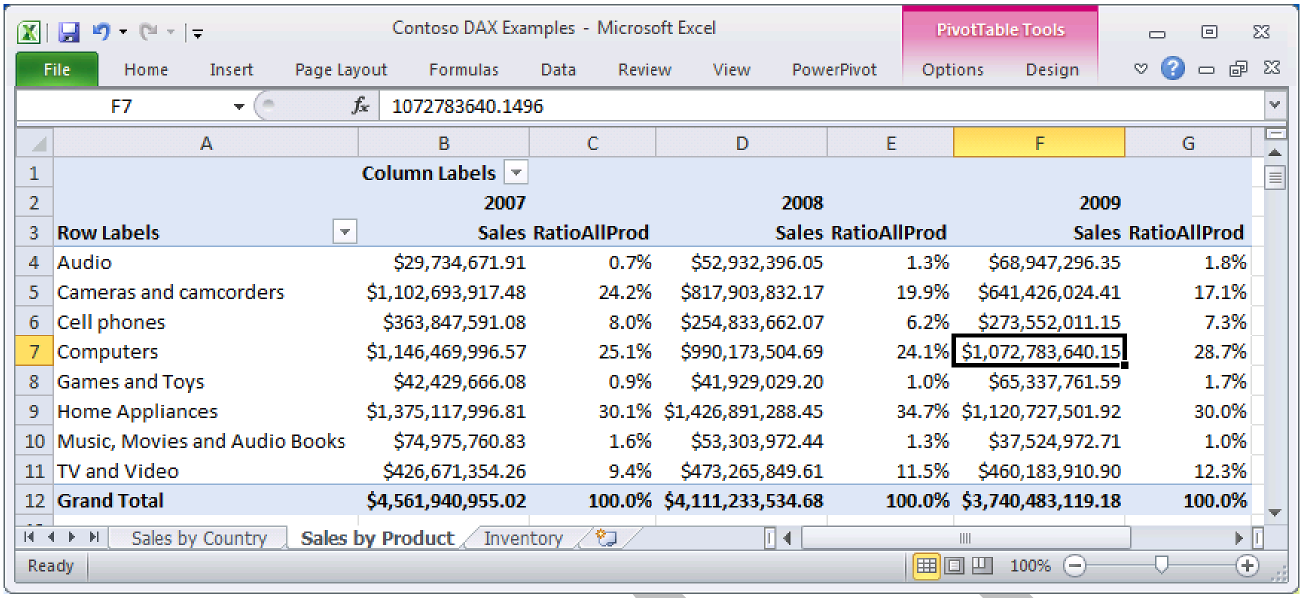


Sales	Column Labels			
Row Labels	2007	2008	2009	Grand Total
Audio	$29,734,671.91	$52,932,396.05	$68,947,296.35	$151,614,364.31
Cameras and camcorders	$1,102,693,917.48	$817,903,832.17	$641,426,024.41	$2,562,023,774.06
Cell phones	$363,847,591.08	$254,833,662.07	$273,552,011.15	$892,233,264.30
Computers	$1,146,469,996.57	$990,173,504.69	$1,072,783,640.15	$3,209,427,141.42
Games and Toys	$42,429,666.08	$41,929,029.20	$65,337,761.59	$149,696,456.86
Home Appliances	$1,375,117,996.81	$1,426,891,288.45	$1,120,727,501.92	$3,922,736,787.19
Music, Movies and Audio Books	$74,975,760.83	$53,303,972.44	$37,524,972.71	$165,804,705.98
TV and Video	$426,671,354.26	$473,265,849.61	$460,183,910.90	$1,360,121,114.76
Grand Total	**$4,561,940,955.02**	**$4,111,233,534.68**	**$3,740,483,119.18**	**$12,413,657,608.89**

Now, let's add another measure to the PivotTable. Let's add RatioAllProd which is the sales for a given context divided by sales for all products (in the same year). There are two ways to write this, one using CALCULATE, and another using our shortcut syntax:

- = [Sales]/CALCULATE([Sales], ALL(DimProduct))
- = [Sales]/[Sales](ALL(DimProduct))

Note that by removing/ignoring the filter context on DimProducts, we are also removing/ignoring the filter context on all tables on the "one" side of a relationship with DimProducts (SubCategory & Category tables.)



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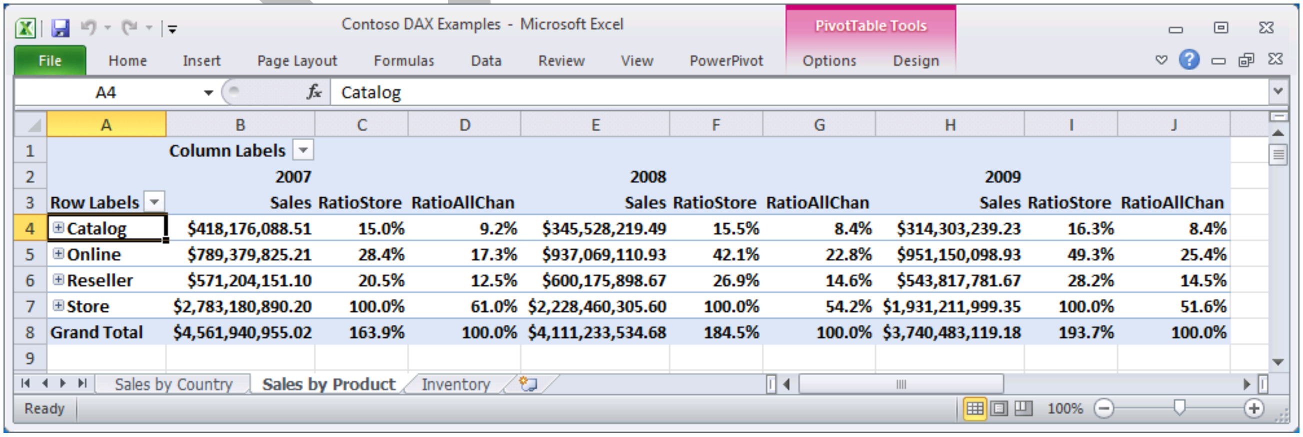
Column Labels	2007		2008		2009	
Row Labels	Sales	RatioAllProd	Sales	RatioAllProd	Sales	RatioAllProd
Audio	$29,734,671.91	0.7%	$52,932,396.05	1.3%	$68,947,296.35	1.8%
Cameras and camcorders	$1,102,693,917.48	24.2%	$817,903,832.17	19.9%	$641,426,024.41	17.1%
Cell phones	$363,847,591.08	8.0%	$254,833,662.07	6.2%	$273,552,011.15	7.3%
Computers	$1,146,469,996.57	25.1%	$990,173,504.69	24.1%	$1,072,783,640.15	28.7%
Games and Toys	$42,429,666.08	0.9%	$41,929,029.20	1.0%	$65,337,761.59	1.7%
Home Appliances	$1,375,117,996.81	30.1%	$1,426,891,288.45	34.7%	$1,120,727,501.92	30.0%
Music, Movies and Audio Books	$74,975,760.83	1.6%	$53,303,972.44	1.3%	$37,524,972.71	1.0%
TV and Video	$426,671,354.26	9.4%	$473,265,849.61	11.5%	$460,183,910.90	12.3%
Grand Total	$4,561,940,955.02	100.0%	$4,111,233,534.68	100.0%	$3,740,483,119.18	100.0%

There is one important thing to note about this formula: = [Sales]/[Sales](ALL(DimProduct)). We have changed the filter context for the denominator of this ratio without changing it for the numerator. This is a very common BI scenario. We need to calculate something compared to that same thing but for a different set of products, or for a different year, or for a different region, etc. Changing some part of the filter context for some portion of the formula is very powerful.

Let's look at one more example, this time comparing sales for each of our four channels to store sales and also to all sales. I'll define two new measures:

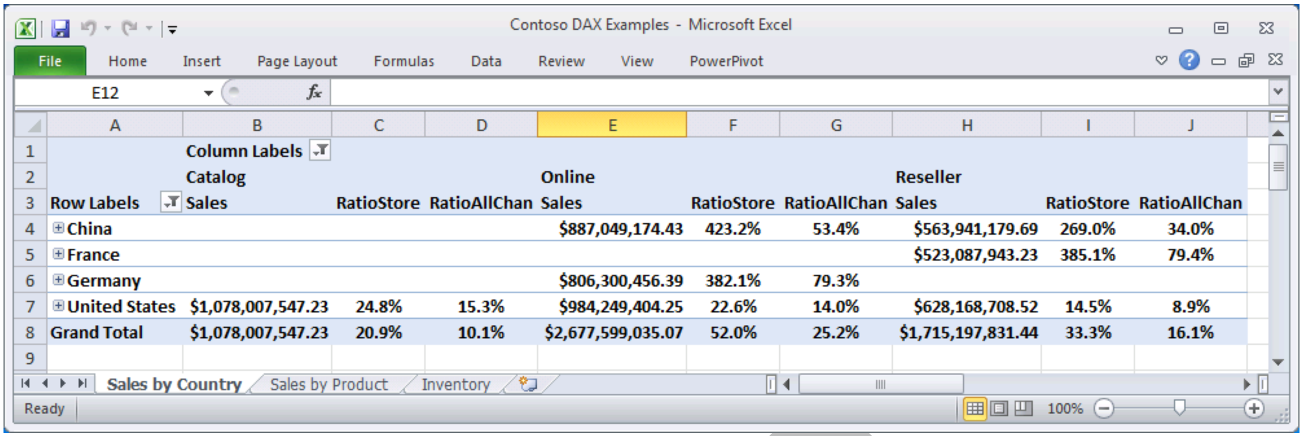
- RatioStore = [Sales]/[StoreSales]
- RatioAllChan = [Sales]/[Sales](ALL(DimChannel))

Then I'll place these measures in a couple of different PivotTable that have different row and column headers to illustrate how a measure can make sense no matter what PivotTable it is placed on. This makes it important to define measures carefully, because once defined, users are free to place them on PivotTables that might be organized quite differently from what was originally anticipated.



Catalog

Column Labels	2007			2008			2009		
Row Labels	Sales	RatioStore	RatioAllChan	Sales	RatioStore	RatioAllChan	Sales	RatioStore	RatioAllChan
⊞Catalog	$418,176,088.51	15.0%	9.2%	$345,528,219.49	15.5%	8.4%	$314,303,239.23	16.3%	8.4%
⊞Online	$789,379,825.21	28.4%	17.3%	$937,069,110.93	42.1%	22.8%	$951,150,098.93	49.3%	25.4%
⊞Reseller	$571,204,151.10	20.5%	12.5%	$600,175,898.67	26.9%	14.6%	$543,817,781.67	28.2%	14.5%
⊞Store	$2,783,180,890.20	100.0%	61.0%	$2,228,460,305.60	100.0%	54.2%	$1,931,211,999.35	100.0%	51.6%
Grand Total	$4,561,940,955.02	163.9%	100.0%	$4,111,233,534.68	184.5%	100.0%	$3,740,483,119.18	193.7%	100.0%



	Column Labels								
	Catalog			Online			Reseller		
Row Labels	Sales	RatioStore	RatioAllChan	Sales	RatioStore	RatioAllChan	Sales	RatioStore	RatioAllChan
⊞China				$887,049,174.43	423.2%	53.4%	$563,941,179.69	269.0%	34.0%
⊞France							$523,087,943.23	385.1%	79.4%
⊞Germany				$806,300,456.39	382.1%	79.3%			
⊞United States	$1,078,007,547.23	24.8%	15.3%	$984,249,404.25	22.6%	14.0%	$628,168,708.52	14.5%	8.9%
Grand Total	$1,078,007,547.23	20.9%	10.1%	$2,677,599,035.07	52.0%	25.2%	$1,715,197,831.44	33.3%	16.1%

5. ALLEXCEPT (Table [,Column1] [,Column2]...)

ALLEXCEPT is a shorthand notation for a series of ALL functions. Imagine a table that has 43 columns, and let's say that you want to remove/ignore the filter context from 40 of those columns, and retain the filter context on three of them. You can accomplish this in two ways:

- ALL(Column1, Column2,... <repeated for 40 columns>) removes the context for the forty columns specified here.
- ALLEXCEPT (Table, Column1, Column2, Column3) removes the context for all the columns in the specified table except the three columns that are specified here.

This is nothing more than a convenient shortcut for specific situations where you want to remove/ignore the context on many (but not all) columns in a table.

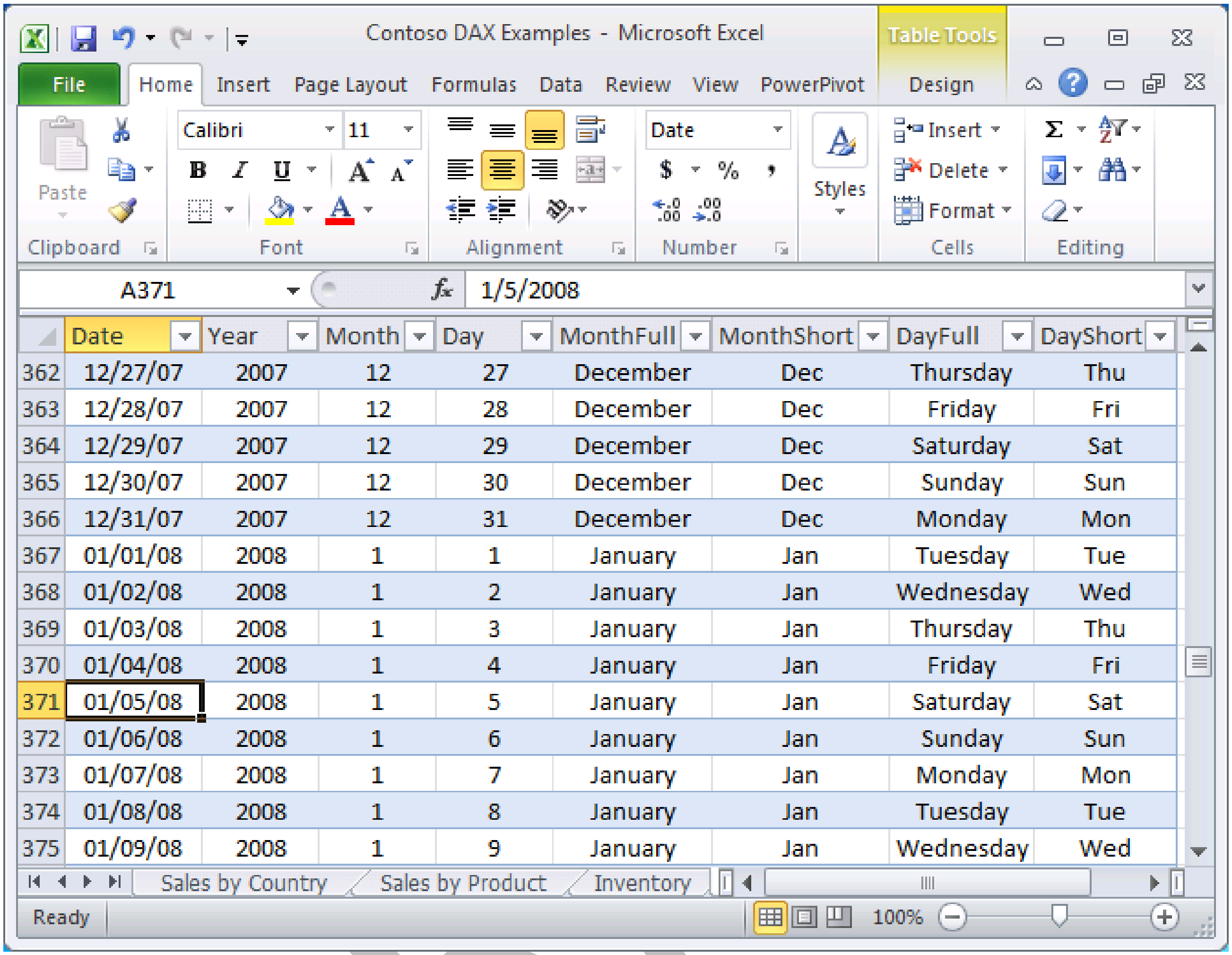
H. Time Intelligence Functions

One of the most common calculations performed in data analysis is to compare some number to a comparable number for a different time period. Calculations that make comparisons to last month or to the same period from a year ago are very important for any business intelligence tool. Toward that end, DAX introduces 35 new functions expressly for the purpose of working with time based data.

1. Concepts and Best Practices

Whenever you are defining measures and working with time periods, there are many opportunities to make bad assumptions about what the PivotTable in which the measure will be used might look like. To avoid a lot of those problems, DAX makes certain assumptions and we recommend certain best practices for anyone planning to use the time intelligence functions described in this section.

We recommend that you create a table in your PowerPivot data that contains one row for every date that might exist in your data. Many people think of this as a date table or a time table or a time dimension. The notion is that this table has one row for each date, and there should be a many to one relationship from any date columns in the database to this date table. Building such a table in Excel is fairly trivial to do, and it might look like the table below, or like the DimDate table in Contoso.



A371 fx 1/5/2008

	Date	Year	Month	Day	MonthFull	MonthShort	DayFull	DayShort
362	12/27/07	2007	12	27	December	Dec	Thursday	Thu
363	12/28/07	2007	12	28	December	Dec	Friday	Fri
364	12/29/07	2007	12	29	December	Dec	Saturday	Sat
365	12/30/07	2007	12	30	December	Dec	Sunday	Sun
366	12/31/07	2007	12	31	December	Dec	Monday	Mon
367	01/01/08	2008	1	1	January	Jan	Tuesday	Tue
368	01/02/08	2008	1	2	January	Jan	Wednesday	Wed
369	01/03/08	2008	1	3	January	Jan	Thursday	Thu
370	01/04/08	2008	1	4	January	Jan	Friday	Fri
371	01/05/08	2008	1	5	January	Jan	Saturday	Sat
372	01/06/08	2008	1	6	January	Jan	Sunday	Sun
373	01/07/08	2008	1	7	January	Jan	Monday	Mon
374	01/08/08	2008	1	8	January	Jan	Tuesday	Tue
375	01/09/08	2008	1	9	January	Jan	Wednesday	Wed

DAX uses this table to construct a set of dates for each calculation. The only column that matters is the date column itself. There are no requirements whatsoever about any of the other columns, and they aren't needed by DAX, although you may find them useful when you build PivotTables. You need to provide a reference to the Date column as an argument to every one of the 35 time intelligence functions in DAX.

In DAX, we always calculate a set of dates as a table and then use that as if it were a SetFilter argument to the CALCULATE function. Consider that a user might have multi-selected some dates within a PivotTable, so that the context for a calculation might be any of the following:

- A single date
- A set of contiguous dates
- A set of non-contiguous dates
- Dates that happen to correspond to a calendar month or quarter or year (very common)

Then consider that we might need to shift those dates to find the following:

- The dates that make up the previous day, month, quarter, or year
- The same dates shifted to a previous month, quarter, or year

- The same dates shifted some interval of time (14 days, 30 days, etc.)
- Dates calculated by shifting an arbitrary interval forward or backward in time

In DAX, we accomplish all of these by working with sets of dates for everything. We don't try to know anything about month or quarter or year columns, but we do know the dates for any given month.

In the initial release of PowerPivot we do not try to handle the many custom calendars that we know exist for financial analysis, but we do allow folks to build those custom calendars by authoring custom formulas to handle such things as 13 four week months in a year, or 4-4-5 quarters, etc.

The built-in functions handle calendar or fiscal years where fiscal year is defined as having a yearend date other than Dec 31. They also know about months, so that when we shift the period April 1-30 back one month, we know that we want March 1-31, and not merely March 1-30. This requires snapping to the end of a month in a variety of situations. In general DAX handles calendar quarters as 3 months, and years as 12 months, so that all of the internal calculations are really based on days or months.

In the next section(s) of this paper, we look at the specific time intelligence functions in DAX and how they work.

2. Functions that return a single date

The functions in this category return a single date. The result of these functions might then be used as arguments to other functions.

The first two functions simply return the first (or last) date in the Date_Column in the current context. This can be useful when you want to find the first (or last) date on which you sold each product, or the first (or last) date on which you had a transaction of a particular type. These functions take only one argument, the name of the date column in your date (or time) table.

- FIRSTDATE (Date_Column)
- LASTDATE (Date_Column)

The next two functions aren't strictly time intelligence functions, because they can be used for other purposes, but they will most often be used for time calculations. They are used to find the first (or last) date (or any other column value as well) where an expression has a non-blank value. This is most often used in situations like inventory, where you want to get the last inventory amount, and you don't happen to know when the last inventory was taken.

- FIRSTNONBLANK (Date_Column, Expression)
- LASTNONBLANK (Date_Column, Expression)

Here's an example from Contoso that shows how to calculate inventory using LASTNONBLANK. Note that this is a fairly complex calculation, so I'm going to take the time to describe it.

Let's look first at the FactInventory table in Contoso. This table contains a set of transactions where inventory was counted for various products in various stores. Each transaction identifies:

- a specific date
- a specific store
- a specific product
- an on-hand quantity

Note that inventory quantities do not add. If I count 3 widgets one day, and 2 widgets a week later, the net result is that I have 2 widgets (until another transaction occurs to change the quantity on hand.) At any moment in time, the on-hand-qty is the last count that was taken of that product in that store.

While inventories do not add within a store and within a product, they do add across stores and across products. If I have 3 apples and 2 oranges in one store, and 5 apples and 4 oranges in another, then I can say that I have a total of 8 apples and 6 oranges, and I can even say that I have a total of 14 products.

So how do I author this formula using DAX? (Warning – I am going to intentionally make a mistake in this process, and will point it out later, along with the necessary adjustment. Please bear with me.)

First, I need to know the quantity on hand for each product in each store. This is where LASTNONBLANK comes in. I also need to add these numbers up across a list of stores and a list of products, which are available to me as the DimStore and DimProduct tables. Consider this pair of formulas:

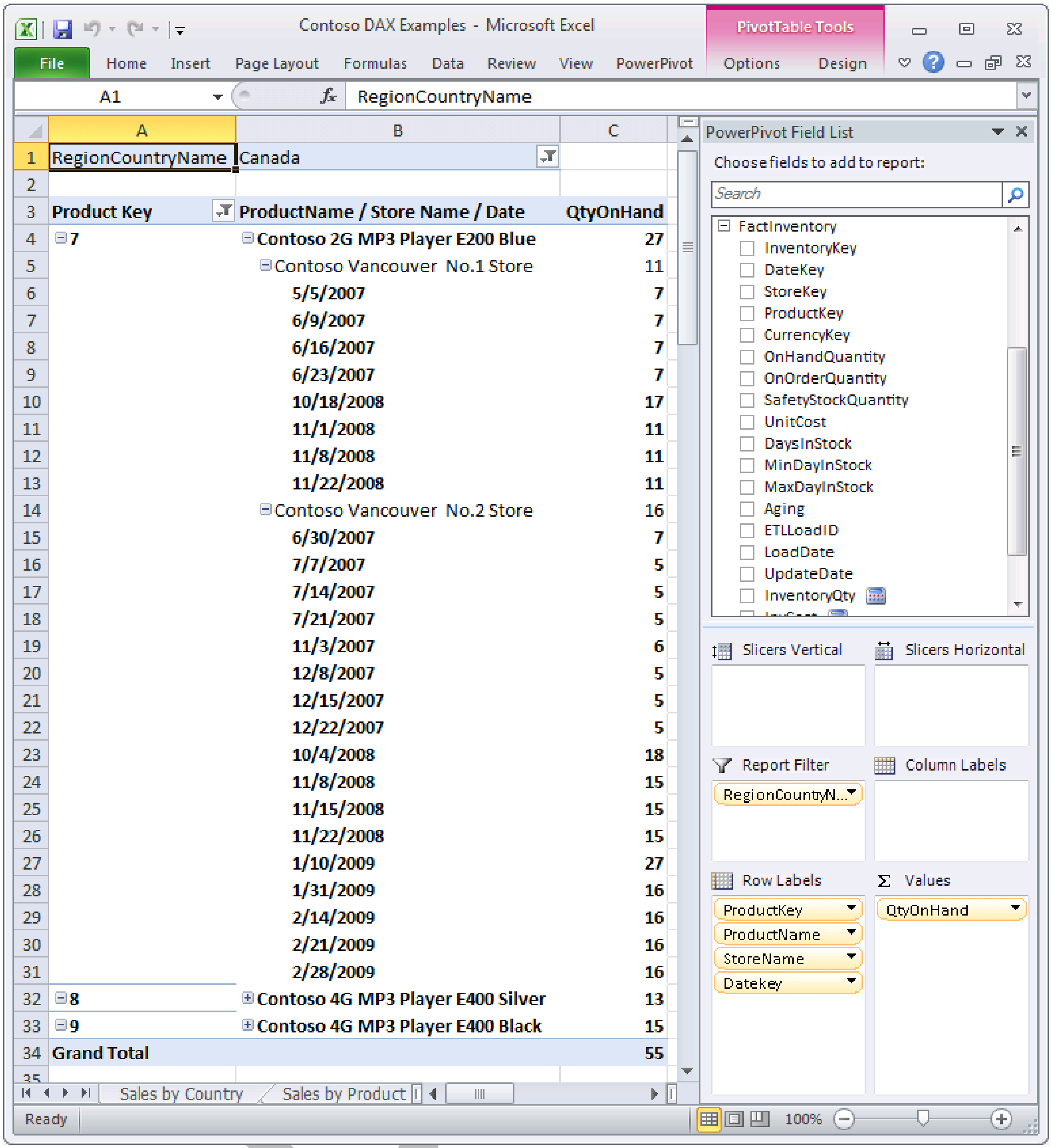
```
[BaseQty] = SUM(FactInventory[OnHandQuantity])

[QtyOnHand] = SUMX(VALUES(DimStore[StoreKey]),
              SUMX(VALUES(DimProduct[ProductKey]),
              CALCULATE([BaseQty],
              LASTNONBLANK(DimDate[Datekey],[BaseQty]))))
```

These formulas say the following:

Define [BaseQty] as the sum of the OnHandQuantity amounts in FactInventory

Define [QtyOnHand] as a nested aggregation (nested sum) where
For each Store,
For each Product,
For the last date where there is a non-blank [BaseQty],
Calculate the [BaseQty],
Then add up those results across products and stores.

A PivotTable with this measure appears (at first glance) to give the right results. Let’s look at this using just a couple of products in a couple of Canadian stores as examples. The last date is used for each product, and the quantities add up across multiple products and stores.



	A	B	C
1	RegionCountryName	Canada	
2			
3	Product Key	ProductName / Store Name / Date	QtyOnHand
4	⊟7	⊟Contoso 2G MP3 Player E200 Blue	27
5		⊟Contoso Vancouver No.1 Store	11
6		5/5/2007	7
7		6/9/2007	7
8		6/16/2007	7
9		6/23/2007	7
10		10/18/2008	17
11		11/1/2008	11
12		11/8/2008	11
13		11/22/2008	11
14		⊟Contoso Vancouver No.2 Store	16
15		6/30/2007	7
16		7/7/2007	5
17		7/14/2007	5
18		7/21/2007	5
19		11/3/2007	6
20		12/8/2007	5
21		12/15/2007	5
22		12/22/2007	5
23		10/4/2008	18
24		11/8/2008	15
25		11/15/2008	15
26		11/22/2008	15
27		1/10/2009	27
28		1/31/2009	16
29		2/14/2009	16
30		2/21/2009	16
31		2/28/2009	16
32	⊟8	⊞Contoso 4G MP3 Player E400 Silver	13
33	⊟9	⊞Contoso 4G MP3 Player E400 Black	15
34	Grand Total		55

PowerPivot Field List

Choose fields to add to report:

⊟ FactInventory
- □ InventoryKey
- □ DateKey
- □ StoreKey
- □ ProductKey
- □ CurrencyKey
- □ OnHandQuantity
- □ OnOrderQuantity
- □ SafetyStockQuantity
- □ UnitCost
- □ DaysInStock
- □ MinDayInStock
- □ MaxDayInStock
- □ Aging
- □ ETLLoadID
- □ LoadDate
- □ UpdateDate
- □ InventoryQty

Slicers Vertical

Slicers Horizontal

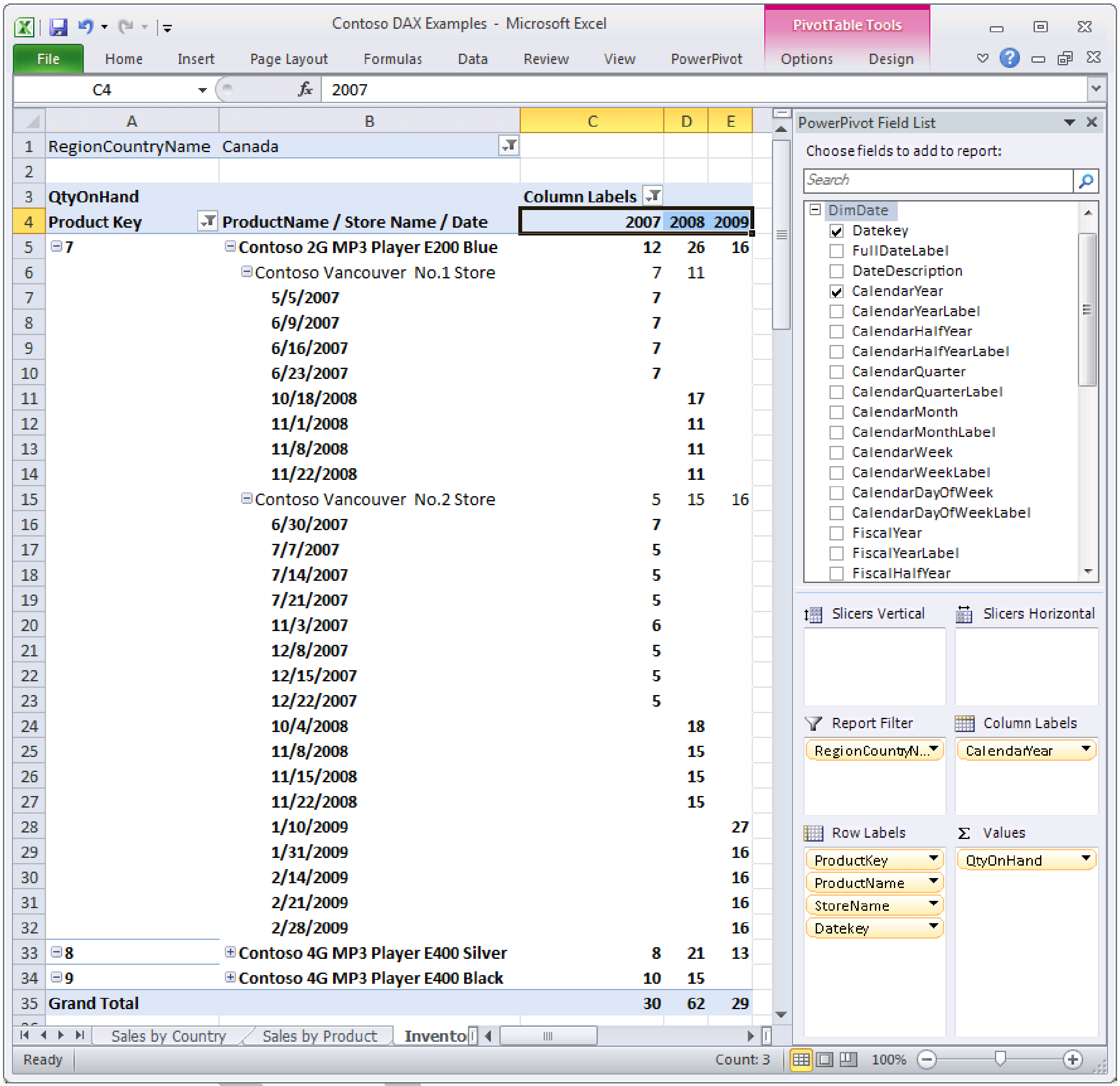
Report Filter: RegionCountryN...

Column Labels

Row Labels: ProductKey, ProductName, StoreName, Datekey

Values: QtyOnHand

So what's the problem? We haven't anticipated what might happen when someone slices this PivotTable using Time. For example, let's add Years to column labels and take another look at the results:



C4 | 2007

	A	B	C	D	E
1	RegionCountryName	Canada			
2					
3	QtyOnHand		Column Labels		
4	Product Key	ProductName / Store Name / Date	2007	2008	2009
5	⊟7	⊟Contoso 2G MP3 Player E200 Blue	12	26	16
6		⊟Contoso Vancouver No.1 Store	7	11	
7		5/5/2007	7		
8		6/9/2007	7		
9		6/16/2007	7		
10		6/23/2007	7		
11		10/18/2008		17	
12		11/1/2008		11	
13		11/8/2008		11	
14		11/22/2008		11	
15		⊟Contoso Vancouver No.2 Store	5	15	16
16		6/30/2007	7		
17		7/7/2007	5		
18		7/14/2007	5		
19		7/21/2007	5		
20		11/3/2007	6		
21		12/8/2007	5		
22		12/15/2007	5		
23		12/22/2007	5		
24		10/4/2008		18	
25		11/8/2008		15	
26		11/15/2008		15	
27		11/22/2008		15	
28		1/10/2009			27
29		1/31/2009			16
30		2/14/2009			16
31		2/21/2009			16
32		2/28/2009			16
33	⊟8	⊞Contoso 4G MP3 Player E400 Silver	8	21	13
34	⊟9	⊞Contoso 4G MP3 Player E400 Black	10	15	
35	Grand Total		30	62	29

PowerPivot Field List

Choose fields to add to report:

⊟ DimDate
- ☑ Datekey
- ☐ FullDateLabel
- ☐ DateDescription
- ☑ CalendarYear
- ☐ CalendarYearLabel
- ☐ CalendarHalfYear
- ☐ CalendarHalfYearLabel
- ☐ CalendarQuarter
- ☐ CalendarQuarterLabel
- ☐ CalendarMonth
- ☐ CalendarMonthLabel
- ☐ CalendarWeek
- ☐ CalendarWeekLabel
- ☐ CalendarDayOfWeek
- ☐ CalendarDayOfWeekLabel
- ☐ FiscalYear
- ☐ FiscalYearLabel
- ☐ FiscalHalfYear

Slicers Vertical | Slicers Horizontal

Report Filter: RegionCountryN...

Column Labels: CalendarYear

Row Labels: ProductKey, ProductName, StoreName, Datekey

Values: QtyOnHand

For Product 7 (Contoso 2G MP3 Player E200 Blue) the last inventory transaction occurs in 2008. When we are doing inventory calculations for 2009, since there are no inventory transactions, we report that there is no inventory. But that's not true, because we still have the inventory left over from 2008.

This means that we need to change our calculation, so that we change the context for time to include all the transactions from the beginning of time up until the current context. In order to do this, we need another time intelligence function that we haven't gotten to yet. We'll come back to this example once we've described the function we'll need.

Six more functions that return a single date are the functions that return the first or last date of a month, quarter, or year within the current context of the calculation.

- STARTOFMONTH (Date_Column)
- STARTOFQUARTER (Date_Column)
- STARTOFYEAR (Date_Column [,YE_Date])
- ENDOFMONTH (Date_Column)
- ENDOFQUARTER (Date_Column)
- ENDOFYEAR (Date_Column [,YE_Date])

3. Functions that return a table of dates

There are sixteen time intelligence functions that return a table of dates. Most often, these functions will be used as a SetFilter argument to CALCULATE. Just like all Time Intelligence functions in DAX, each function takes a column of dates as one of its arguments.

The first eight functions in this category are reasonably straightforward. Each of these functions starts with a date column in a current context. For example, if we are calculating a measure in a PivotTable, there might be a month or year on either the column labels or row labels. The net effect is that the date column is filtered to include only the dates for the current context. Starting from that current context, these eight functions then calculate the previous (or next) day, month, quarter, or year and return those dates in the form of a single column table. Note that the “previous” functions work backward from the first date in the current context, and the “next” functions move forward from the last date in the current context.

- PREVIOUSDAY (Date_Column)
- PREVIOUSMONTH (Date_Column)
- PREVIOUSQUARTER (Date_Column)
- PREVIOUSYEAR (Date_Column [,YE_Date])
- NEXTDAY (Date_Column)
- NEXTMONTH (Date_Column)
- NEXTQUARTER (Date_Column)
- NEXTYEAR (Date_Column [,YE_Date])

The next four functions in this category are similar, but instead of calculating a previous (or next) period, they calculate the set of dates in the period that is “month-to-date” (or quarter-to-date, or year-to-date, or in the same period of the previous year). These functions all perform their calculations using the last date in the current context. Note that SAMEPERIODLASTYEAR requires that the current context contain a contiguous set of dates. If the current context is not a contiguous set of dates, then SAMEPERIODLASTYEAR will return an error.

- DATESMTD (Date_Column)
- DATESQTD (Date_Column)
- DATESYTD (Date_Column [,YE_Date])
- SAMEPERIODLASTYEAR (Date_Column)

The last four functions in this category are a bit more complex, and also a bit more powerful. These functions are used to shift from the set of dates that are in the current context to a new set of dates.

- DATEADD (Date_Column, Number_of_Intervals, Interval)

- DATESBETWEEN (Date_Column, Start_Date, End_Date)
- DATESINPERIOD (Date_Column, Start_Date, Number_of_Intervals, Interval)
- PARALLELPERIOD (Date_Column, Number_of_Intervals, Interval)

DATESBETWEEN calculates the set of dates between the specified start date and end date. The remaining three functions shift some number of time intervals from the current context. The interval can be day, month, quarter or year. These functions make it very easy to shift the time interval for a calculation by any of the following:

- Go back two years
- Go back one month
- Go forward three quarters
- Go back 14 days
- Go forward 28 days

In each case, we only need to specify which interval, and how many of those intervals we want to shift. A positive interval will move forward in time, while a negative interval will move back in time. The interval itself is specified by a keyword of DAY, MONTH, QUARTER, or YEAR. Note that these keywords are not strings, so they should not be in quotation marks. It’s also useful to note that auto-complete doesn’t yet help to fill in these keywords, so you simply have to type them in.

Let’s look at some examples of how these functions might be used with the Contoso data set:

Year over Year Growth

The problem I want to solve is to calculate year-over-year growth for Store Sales. Although we’ve had formulas for StoreSales earlier in this paper (based on a [Sales] measure) let’s assume that formula is no longer handy and we want to start over with the Contoso database. A formula that might have seemed complicated before is now pretty straightforward:

[StoreSales] = CALCULATE (SUM (FactSales[SalesAmount]), DimChannel[ChannelName]="Store")

In other words, Store Sales is defined as the sum of the SalesAmount column in the FactSales table, with the context modified to include only sales where the Channel Name in the DimChannel table is “Store”.

Now we want to calculate StoreSales for the previous year.

[StoreSalesPrevYr] = CALCULATE([StoreSales], DATEADD(DimDate[DateKey], -1, YEAR))

Since we’re calculating a single measure in a modified context, this can be written using a syntax shortcut.

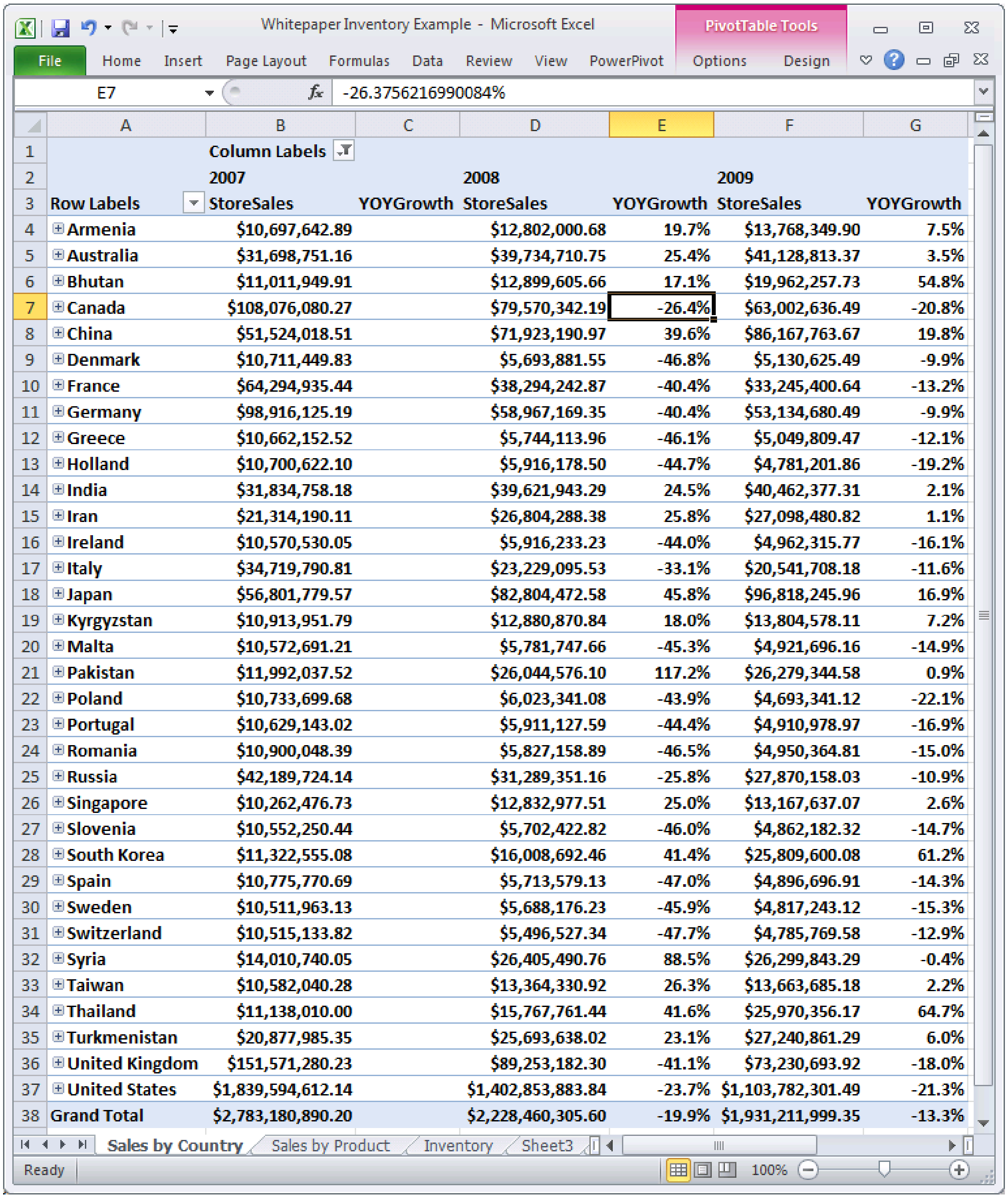
[StoreSalesPrevYr] = [StoreSales](DATEADD(DimDate[DateKey], -1, YEAR))

Now we can calculate Year over Year Growth by simply subtracting last year’s sales from this year’s sales and showing that difference as a percentage of last year’s sales.

[YOYGrowth] = ([StoreSales] - [StoreSalesPrevYr])/[StoreSalesPrevYr]

Finally we need to wrap this in an IF statement, so we don't get division by zero in the first year.
[YOYGrowth] = IF ([StoreSalesPrevYr], ([StoreSales] - [StoreSalesPrevYr])/[StoreSalesPrevYr], BLANK())

Place [StoresSales] and [YOYGrowth] in a PivotTable with countries on rows, and years on columns:



E7 *fx* -26.3756216990084%

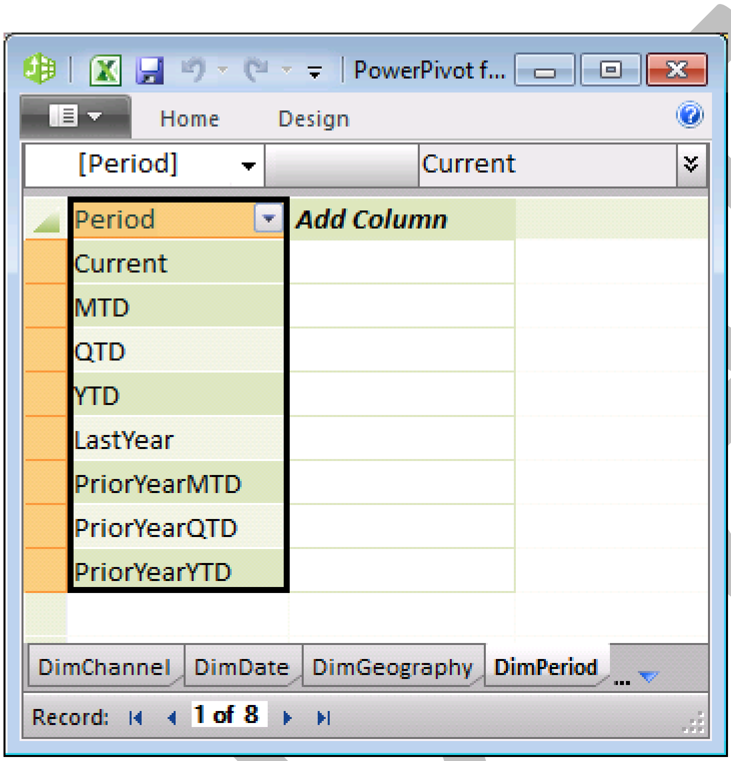
	A	B	C	D	E	F	G
1		Column Labels					
2		2007		2008		2009	
3	Row Labels	StoreSales	YOYGrowth	StoreSales	YOYGrowth	StoreSales	YOYGrowth
4	⊞Armenia	$10,697,642.89		$12,802,000.68	19.7%	$13,768,349.90	7.5%
5	⊞Australia	$31,698,751.16		$39,734,710.75	25.4%	$41,128,813.37	3.5%
6	⊞Bhutan	$11,011,949.91		$12,899,605.66	17.1%	$19,962,257.73	54.8%
7	⊞Canada	$108,076,080.27		$79,570,342.19	-26.4%	$63,002,636.49	-20.8%
8	⊞China	$51,524,018.51		$71,923,190.97	39.6%	$86,167,763.67	19.8%
9	⊞Denmark	$10,711,449.83		$5,693,881.55	-46.8%	$5,130,625.49	-9.9%
10	⊞France	$64,294,935.44		$38,294,242.87	-40.4%	$33,245,400.64	-13.2%
11	⊞Germany	$98,916,125.19		$58,967,169.35	-40.4%	$53,134,680.49	-9.9%
12	⊞Greece	$10,662,152.52		$5,744,113.96	-46.1%	$5,049,809.47	-12.1%
13	⊞Holland	$10,700,622.10		$5,916,178.50	-44.7%	$4,781,201.86	-19.2%
14	⊞India	$31,834,758.18		$39,621,943.29	24.5%	$40,462,377.31	2.1%
15	⊞Iran	$21,314,190.11		$26,804,288.38	25.8%	$27,098,480.82	1.1%
16	⊞Ireland	$10,570,530.05		$5,916,233.23	-44.0%	$4,962,315.77	-16.1%
17	⊞Italy	$34,719,790.81		$23,229,095.53	-33.1%	$20,541,708.18	-11.6%
18	⊞Japan	$56,801,779.57		$82,804,472.58	45.8%	$96,818,245.96	16.9%
19	⊞Kyrgyzstan	$10,913,951.79		$12,880,870.84	18.0%	$13,804,578.11	7.2%
20	⊞Malta	$10,572,691.21		$5,781,747.66	-45.3%	$4,921,696.16	-14.9%
21	⊞Pakistan	$11,992,037.52		$26,044,576.10	117.2%	$26,279,344.58	0.9%
22	⊞Poland	$10,733,699.68		$6,023,341.08	-43.9%	$4,693,341.12	-22.1%
23	⊞Portugal	$10,629,143.02		$5,911,127.59	-44.4%	$4,910,978.97	-16.9%
24	⊞Romania	$10,900,048.39		$5,827,158.89	-46.5%	$4,950,364.81	-15.0%
25	⊞Russia	$42,189,724.14		$31,289,351.16	-25.8%	$27,870,158.03	-10.9%
26	⊞Singapore	$10,262,476.73		$12,832,977.51	25.0%	$13,167,637.07	2.6%
27	⊞Slovenia	$10,552,250.44		$5,702,422.82	-46.0%	$4,862,182.32	-14.7%
28	⊞South Korea	$11,322,555.08		$16,008,692.46	41.4%	$25,809,600.08	61.2%
29	⊞Spain	$10,775,770.69		$5,713,579.13	-47.0%	$4,896,696.91	-14.3%
30	⊞Sweden	$10,511,963.13		$5,688,176.23	-45.9%	$4,817,243.12	-15.3%
31	⊞Switzerland	$10,515,133.82		$5,496,527.34	-47.7%	$4,785,769.58	-12.9%
32	⊞Syria	$14,010,740.05		$26,405,490.76	88.5%	$26,299,843.29	-0.4%
33	⊞Taiwan	$10,582,040.28		$13,364,330.92	26.3%	$13,663,685.18	2.2%
34	⊞Thailand	$11,138,010.00		$15,767,761.44	41.6%	$25,970,356.17	64.7%
35	⊞Turkmenistan	$20,877,985.35		$25,693,638.02	23.1%	$27,240,861.29	6.0%
36	⊞United Kingdom	$151,571,280.23		$89,253,182.30	-41.1%	$73,230,693.92	-18.0%
37	⊞United States	$1,839,594,612.14		$1,402,853,883.84	-23.7%	$1,103,782,301.49	-21.3%
38	Grand Total	$2,783,180,890.20		$2,228,460,305.60	-19.9%	$1,931,211,999.35	-13.3%

Calculating many time periods within a single measure formula

Consider the following eight calculations. Each of these formulas calculates a sales amount (in the Contoso database) for a distinct time period.

Time Period	Formula
Current Period	=[Sales]
MTD	= [Sales](DATESMTD(DimDate[Datekey]))
QTD	= [Sales](DATESQTD(DimDate[Datekey]))
YTD	= [Sales](DATESYTD(DimDate[Datekey])),
Current Period Last Year	= [Sales](DATEADD(DimDate[Datekey],-1,YEAR))
PriorYearMTD	= [Sales](DATEADD(DATESMTD(DimDate[Datekey]),-1,YEAR))
PriorYearQTD	= [Sales](DATEADD(DATESQTD(DimDate[Datekey]),-1,YEAR))
PriorYearYTD	= [Sales](DATEADD(DATESYTD(DimDate[Datekey]),-1,YEAR))

Let's create a new table named DimPeriod in PowerPivot that has a single column named Period, by pasting in a set of text strings like this from Excel:



Period
Current
MTD
QTD
YTD
LastYear
PriorYearMTD
PriorYearQTD
PriorYearYTD

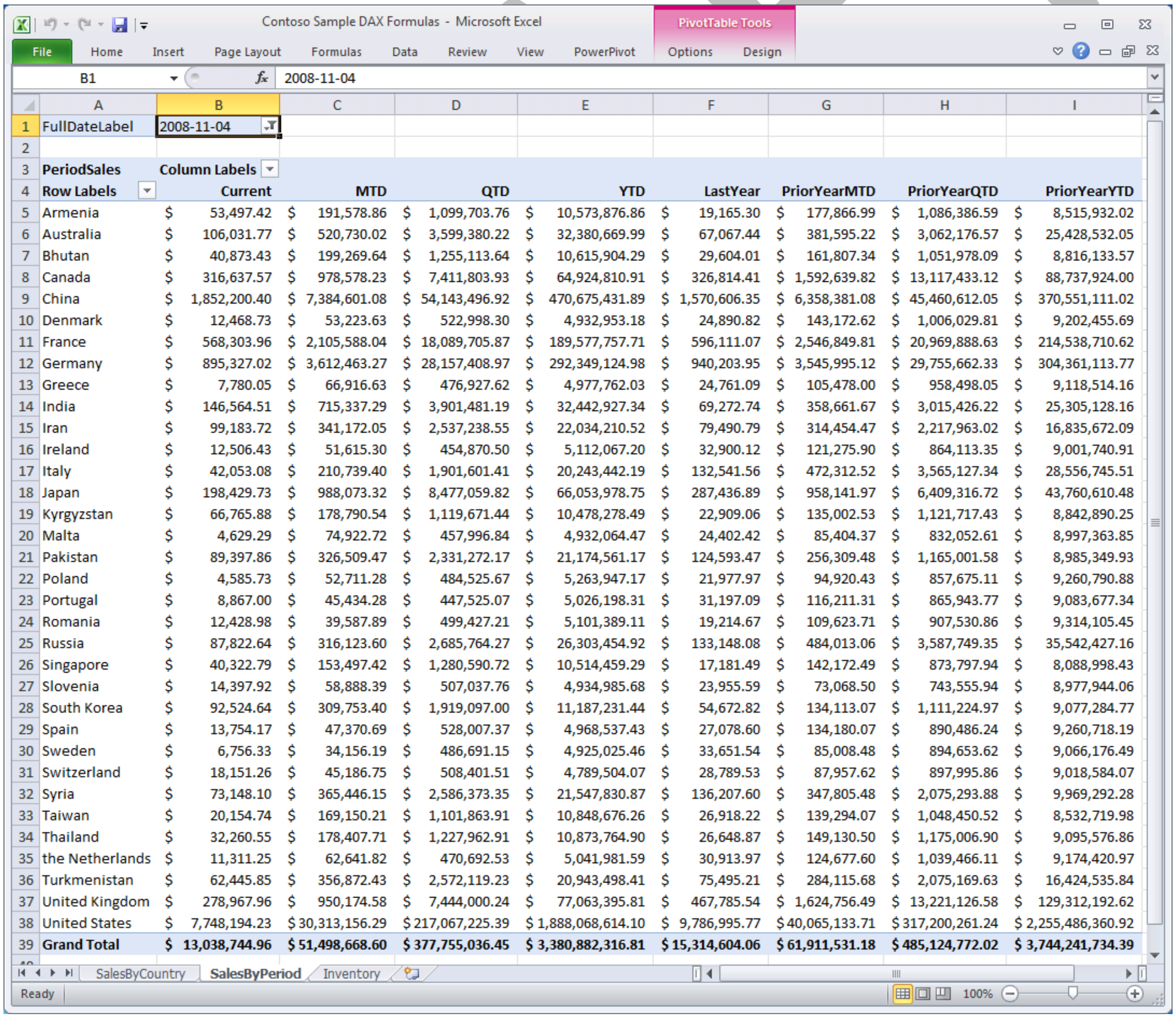
Now let's build a single measure formula that does the following:

1. Use an IF function, to see if the DimPeriod[Period] column has been placed into the Filter Context by placing this column onto the PivotTable's column labels, or row labels, or perhaps on a slicer. The best way is to count the number of values that are applicable from this column. If this isn't in the filter context, all 8 values will be applicable. But if this is on columns or rows, then only one of the values will be applicable for each cell in the values area (except for the Total row/column).
2. If only one of these values is applicable, then use nested IF statements to see which one it is, and apply the appropriate formula.
3. If this column is not on rows or columns (or selected to a single value in a slicer) then assume that the user wants Current sales figure instead of one of the more elaborate calculations.

Such a formula would look like this:

```
=IF( COUNTROWS( VALUES( DimPeriod[Period]))=1,
  IF( VALUES( DimPeriod[Period]) = "Current", [Sales],
  IF( VALUES( DimPeriod[Period]) = "MTD", [Sales](DATESMTD(DimDate[Datekey])),
  IF( VALUES( DimPeriod[Period]) = "QTD", [Sales](DATESQTD(DimDate[Datekey])),
  IF( VALUES( DimPeriod[Period]) = "YTD", [Sales](DATESYTD(DimDate[Datekey])),
  IF( VALUES( DimPeriod[Period]) = "LastYear", [Sales](DATEADD(DimDate[Datekey],-1,YEAR)),
  IF( VALUES( DimPeriod[Period]) = "PriorYearMTD", [Sales](DATEADD(DATESMTD(DimDate[Datekey]),-1,YEAR)),
  IF( VALUES( DimPeriod[Period]) = "PriorYearQTD", [Sales](DATEADD(DATESQTD(DimDate[Datekey]),-1,YEAR)),
  IF( VALUES( DimPeriod[Period]) = "PriorYearYTD", [Sales](DATEADD(DATESYTD(DimDate[Datekey]),-1,YEAR)),
  BLANK())))))))),[Sales])
```

Now if I build a PivotTable with DimGeography[RegionCountryName] on row labels, DimPeriod[Period] on column labels, a single date from DimDate[FullDateLabel] in the Report Filter, and my new formula as the only measure, I'll get a PivotTable that looks like this:



FullDateLabel 2008-11-04

PeriodSales	Column Labels							
Row Labels	Current	MTD	QTD	YTD	LastYear	PriorYearMTD	PriorYearQTD	PriorYearYTD
Armenia	$ 53,497.42	$ 191,578.86	$ 1,099,703.76	$ 10,573,876.86	$ 19,165.30	$ 177,866.99	$ 1,086,386.59	$ 8,515,932.02
Australia	$ 106,031.77	$ 520,730.02	$ 3,599,380.22	$ 32,380,669.99	$ 67,067.44	$ 381,595.22	$ 3,062,176.57	$ 25,428,532.05
Bhutan	$ 40,873.43	$ 199,269.64	$ 1,255,113.64	$ 10,615,904.29	$ 29,604.01	$ 161,807.34	$ 1,051,978.09	$ 8,816,133.57
Canada	$ 316,637.57	$ 978,578.23	$ 7,411,803.93	$ 64,924,810.91	$ 326,814.41	$ 1,592,639.82	$ 13,117,433.12	$ 88,737,924.00
China	$ 1,852,200.40	$ 7,384,601.08	$ 54,143,496.92	$ 470,675,431.89	$ 1,570,606.35	$ 6,358,381.08	$ 45,460,612.05	$ 370,551,111.02
Denmark	$ 12,468.73	$ 53,223.63	$ 522,998.30	$ 4,932,953.18	$ 24,890.82	$ 143,172.62	$ 1,006,029.81	$ 9,202,455.69
France	$ 568,303.96	$ 2,105,588.04	$ 18,089,705.87	$ 189,577,757.71	$ 596,111.07	$ 2,546,849.81	$ 20,969,888.63	$ 214,538,710.62
Germany	$ 895,327.02	$ 3,612,463.27	$ 28,157,408.97	$ 292,349,124.98	$ 940,203.95	$ 3,545,995.12	$ 29,755,662.33	$ 304,361,113.77
Greece	$ 7,780.05	$ 66,916.63	$ 476,927.62	$ 4,977,762.03	$ 24,761.09	$ 105,478.00	$ 958,498.05	$ 9,118,514.16
India	$ 146,564.51	$ 715,337.29	$ 3,901,481.19	$ 32,442,927.34	$ 69,272.74	$ 358,661.67	$ 3,015,426.22	$ 25,305,128.16
Iran	$ 99,183.72	$ 341,172.05	$ 2,537,238.55	$ 22,034,210.52	$ 79,490.79	$ 314,454.47	$ 2,217,963.02	$ 16,835,672.09
Ireland	$ 12,506.43	$ 51,615.30	$ 454,870.50	$ 5,112,067.20	$ 32,900.12	$ 121,275.90	$ 864,113.35	$ 9,001,740.91
Italy	$ 42,053.08	$ 210,739.40	$ 1,901,601.41	$ 20,243,442.19	$ 132,541.56	$ 472,312.52	$ 3,565,127.34	$ 28,556,745.51
Japan	$ 198,429.73	$ 988,073.32	$ 8,477,059.82	$ 66,053,978.75	$ 287,436.89	$ 958,141.97	$ 6,409,316.72	$ 43,760,610.48
Kyrgyzstan	$ 66,765.88	$ 178,790.54	$ 1,119,671.44	$ 10,478,278.49	$ 22,909.06	$ 135,002.53	$ 1,121,717.43	$ 8,842,890.25
Malta	$ 4,629.29	$ 74,922.72	$ 457,996.84	$ 4,932,064.47	$ 24,402.42	$ 85,404.37	$ 832,052.61	$ 8,997,363.85
Pakistan	$ 89,397.86	$ 326,509.47	$ 2,331,272.17	$ 21,174,561.17	$ 124,593.47	$ 256,309.48	$ 1,165,001.58	$ 8,985,349.93
Poland	$ 4,585.73	$ 52,711.28	$ 484,525.67	$ 5,263,947.17	$ 21,977.97	$ 94,920.43	$ 857,675.11	$ 9,260,790.88
Portugal	$ 8,867.00	$ 45,434.28	$ 447,525.07	$ 5,026,198.31	$ 31,197.09	$ 116,211.31	$ 865,943.77	$ 9,083,677.34
Romania	$ 12,428.98	$ 39,587.89	$ 499,427.21	$ 5,101,389.11	$ 19,214.67	$ 109,623.71	$ 907,530.86	$ 9,314,105.45
Russia	$ 87,822.64	$ 316,123.60	$ 2,685,764.27	$ 26,303,454.92	$ 133,148.08	$ 484,013.06	$ 3,587,749.35	$ 35,542,427.16
Singapore	$ 40,322.79	$ 153,497.42	$ 1,280,590.72	$ 10,514,459.29	$ 17,181.49	$ 142,172.49	$ 873,797.94	$ 8,088,998.43
Slovenia	$ 14,397.92	$ 58,888.39	$ 507,037.76	$ 4,934,985.68	$ 23,955.59	$ 73,068.50	$ 743,555.94	$ 8,977,944.06
South Korea	$ 92,524.64	$ 309,753.40	$ 1,919,097.00	$ 11,187,231.44	$ 54,672.82	$ 134,113.07	$ 1,111,224.97	$ 9,077,284.77
Spain	$ 13,754.17	$ 47,370.69	$ 528,007.37	$ 4,968,537.43	$ 27,078.60	$ 134,180.07	$ 890,486.24	$ 9,260,718.19
Sweden	$ 6,756.33	$ 34,156.19	$ 486,691.15	$ 4,925,025.46	$ 33,651.54	$ 85,008.48	$ 894,653.62	$ 9,066,176.49
Switzerland	$ 18,151.26	$ 45,186.75	$ 508,401.51	$ 4,789,504.07	$ 28,789.53	$ 87,957.62	$ 897,995.86	$ 9,018,584.07
Syria	$ 73,148.10	$ 365,446.15	$ 2,586,373.35	$ 21,547,830.87	$ 136,207.60	$ 347,805.48	$ 2,075,293.88	$ 9,969,292.28
Taiwan	$ 20,154.74	$ 169,150.21	$ 1,101,863.91	$ 10,848,676.26	$ 26,918.22	$ 139,294.07	$ 1,048,450.52	$ 8,532,719.98
Thailand	$ 32,260.55	$ 178,407.71	$ 1,227,962.91	$ 10,873,764.90	$ 26,648.87	$ 149,130.50	$ 1,175,006.90	$ 9,095,576.86
the Netherlands	$ 11,311.25	$ 62,641.82	$ 470,692.53	$ 5,041,981.59	$ 30,913.97	$ 124,677.60	$ 1,039,466.11	$ 9,174,420.97
Turkmenistan	$ 62,445.85	$ 356,872.43	$ 2,572,119.23	$ 20,943,498.41	$ 75,495.21	$ 284,115.68	$ 2,075,169.63	$ 16,424,535.84
United Kingdom	$ 278,967.96	$ 950,174.58	$ 7,444,000.24	$ 77,063,395.81	$ 467,785.54	$ 1,624,756.49	$ 13,221,126.58	$ 129,312,192.62
United States	$ 7,748,194.23	$ 30,313,156.29	$ 217,067,225.39	$ 1,888,068,614.10	$ 9,786,995.77	$ 40,065,133.71	$ 317,200,261.24	$ 2,255,486,360.92
Grand Total	**$ 13,038,744.96**	**$ 51,498,668.60**	**$ 377,755,036.45**	**$ 3,380,882,316.81**	**$ 15,314,604.06**	**$ 61,911,531.18**	**$ 485,124,772.02**	**$ 3,744,241,734.39**

Finishing up our Inventory Scenario

We now have the functions we need to finish up the Inventory problem we were looking at.

The formula we had before was:

```
[QtyOnHand] = SUMX(VALUES(DimStore[StoreKey]),
              SUMX(VALUES(DimProduct[ProductKey]),
              CALCULATE([BaseQty],
              LASTNONBLANK(DimDate[Datekey],[BaseQty]))))
```

And the problem was that LASTNONBLANK was getting the last non-blank date from within the current context, when it should have been considering a larger time period. For example, when we are calculating inventory for 2009, we need to consider the last time inventory was taken from the beginning of time up through 2009. When in the context of the year 2009, the formula above only considers inventory transactions within 2009, and doesn't consider transactions that may have occurred prior to 2009.

We can fix the formula by using DATESBETWEEN whose function signature looks like this:

```
DATESBETWEEN (Date_Column, Start_Date, End_Date)
```

We'll use a blank start date (to signify that we want to start at the absolute beginning, and we'll use the last date from the current context as our end date. This means that we want this expression:

```
DATESBETWEEN (DimDate[DateKey], BLANK(), LASTDATE(DimDate[DateKey]))
```

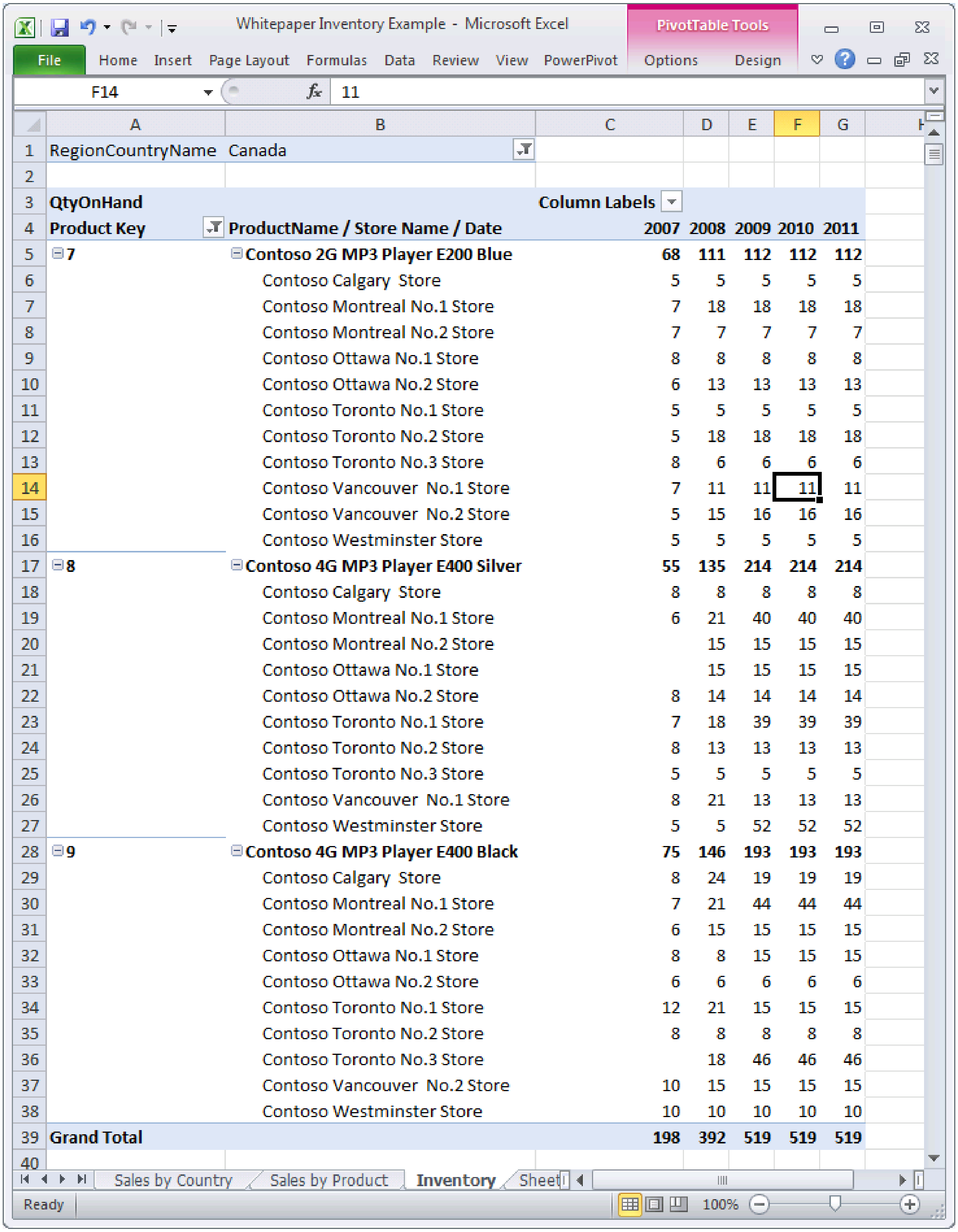
And we'll use this expression in place of the date column in LASTNONBLANK, since we want LASTNONBLANK to consider the expanded range of dates:

```
[QtyOnHand] = SUMX(VALUES(DimStore[StoreKey]),
              SUMX(VALUES(DimProduct[ProductKey]),
              CALCULATE([BaseQty],
              LASTNONBLANK(
              DATESBETWEEN (DimDate[DateKey], BLANK(), LASTDATE(DimDate[DateKey])),
               [BaseQty]))))
```

Note that we could have used our syntax shortcut for CALCULATE (<measure>) here as well:

```
[QtyOnHand] = SUMX(VALUES(DimStore[StoreKey]),
              SUMX(VALUES(DimProduct[ProductKey]),
              [BaseQty]( LASTNONBLANK(
              DATESBETWEEN (DimDate[DateKey], BLANK(), LASTDATE(DimDate[DateKey])),
              [BaseQty]))))
```

The good news is that our inventory now looks correct across dates, and items last counted in 2008 appear in the inventory for 2009 as well as for 2010 and 2011, where we know we have no inventory transactions.



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	A	B	C	D	E	F	G
1	RegionCountryName	Canada					
2							
3	**QtyOnHand**		**Column Labels**				
4	**Product Key**	**ProductName / Store Name / Date**	**2007**	**2008**	**2009**	**2010**	**2011**
5	**⊟7**	**⊟Contoso 2G MP3 Player E200 Blue**	**68**	**111**	**112**	**112**	**112**
6		Contoso Calgary Store	5	5	5	5	5
7		Contoso Montreal No.1 Store	7	18	18	18	18
8		Contoso Montreal No.2 Store	7	7	7	7	7
9		Contoso Ottawa No.1 Store	8	8	8	8	8
10		Contoso Ottawa No.2 Store	6	13	13	13	13
11		Contoso Toronto No.1 Store	5	5	5	5	5
12		Contoso Toronto No.2 Store	5	18	18	18	18
13		Contoso Toronto No.3 Store	8	6	6	6	6
14		Contoso Vancouver No.1 Store	7	11	11	11	11
15		Contoso Vancouver No.2 Store	5	15	16	16	16
16		Contoso Westminster Store	5	5	5	5	5
17	**⊟8**	**⊟Contoso 4G MP3 Player E400 Silver**	**55**	**135**	**214**	**214**	**214**
18		Contoso Calgary Store	8	8	8	8	8
19		Contoso Montreal No.1 Store	6	21	40	40	40
20		Contoso Montreal No.2 Store		15	15	15	15
21		Contoso Ottawa No.1 Store		15	15	15	15
22		Contoso Ottawa No.2 Store	8	14	14	14	14
23		Contoso Toronto No.1 Store	7	18	39	39	39
24		Contoso Toronto No.2 Store	8	13	13	13	13
25		Contoso Toronto No.3 Store	5	5	5	5	5
26		Contoso Vancouver No.1 Store	8	21	13	13	13
27		Contoso Westminster Store	5	5	52	52	52
28	**⊟9**	**⊟Contoso 4G MP3 Player E400 Black**	**75**	**146**	**193**	**193**	**193**
29		Contoso Calgary Store	8	24	19	19	19
30		Contoso Montreal No.1 Store	7	21	44	44	44
31		Contoso Montreal No.2 Store	6	15	15	15	15
32		Contoso Ottawa No.1 Store	8	8	15	15	15
33		Contoso Ottawa No.2 Store	6	6	6	6	6
34		Contoso Toronto No.1 Store	12	21	15	15	15
35		Contoso Toronto No.2 Store	8	8	8	8	8
36		Contoso Toronto No.3 Store		18	46	46	46
37		Contoso Vancouver No.2 Store	10	15	15	15	15
38		Contoso Westminster Store	10	10	10	10	10
39	**Grand Total**		**198**	**392**	**519**	**519**	**519**
40							

4. Functions that evaluate expressions over a time period

There is one more set of Time Intelligence functions in DAX – these are the functions that evaluate an expression over a specified time period. These functions are all provided as a convenience. You can accomplish the same thing using CALCULATE and other Time Intelligence functions. For example,

```
= TOTALMTD (Expression, Date_Column [, SetFilter])
```

is precisely the same as this combination of functions:

```
= CALCULATE (Expression, DATESMTD (Date_Column)[, SetFilter])
```

But it will be simpler and easier for users to use these DAX functions when they are a good fit for the problem that needs to be solved. The DAX functions that do this are:

- TOTALMTD (Expression, Date_Column [, SetFilter])
- TOTALQTD (Expression, Date_Column [, SetFilter])
- TOTALYTD (Expression, Date_Column [, SetFilter] [,YE_Date])

For the functions that calculate opening and closing balances, there are certain concepts that are useful. First, as you might think obvious, the opening balance for any period is the same as the closing balance for the previous period. The closing balance includes all data through the end of the period, while the opening balance does not include any data from within the current period.

These functions always return the value of an expression evaluated for a specific point in time. The point in time we care about is always the last possible date value in a calendar period. The opening balance is based on the last date of the previous period, while the closing balance is based on the last date in the current period. The current period is always determined by the last date in the current date context.

- OPENINGBALANCEMONTH (Expression, Date_Column [,SetFilter])
- OPENINGBALANCEQUARTER Quarter (Expression, Date_Column [,SetFilter])
- OPENINGBALANCEYEAR (Expression, Date_Column [,SetFilter] [,YE_Date])
- CLOSINGBALANCEMONTH (Expression, Date_Column [,SetFilter])
- CLOSINGBALANCEQUARTER (Expression, Date_Column [,SetFilter])
- CLOSINGBALANCEYEAR (Expression, Date_Column [,SetFilter] [,YE_Date])

I. Sample Formulas

Here are some sample formulas meant to illustrate how DAX formulas might be used to address specific business problems. This list is not intended to be complete, but simply to illustrate specific scenarios. All of these formulas will work with the Contoso sample database, once you have defined a simple measure named Sales using this formula: = SUM(FactSales[SalesAmount]). Many of these samples are formulas that have already been described in this document.

1. Calculated Columns

Formulas in calculated columns aren't conceptually different from formulas in Excel. DAX does add some new functions, especially in the areas of aggregation and getting data from related tables.

Sample Formula	**Comments**
=FactSales[SalesQuantity] * FactSales[UnitCost]	same formula as in Excel
=RELATED(DimProduct[Size])	get value from related table
= FactSales[SalesQuantity] * RELATED(DimProduct[UnitCost])	get part of calculation from other table
=SUMX(RELATEDTABLE(FactSales),FactSales[SalesAmount])	sum over related rows in other table
=COUNTROWS(RELATEDTABLE(FactSales))	count related rows in other table
=DimProduct[UnitCost] / AVERAGEX(ALL(DimProduct),DimProduct[UnitCost])	ratio of this product's unit cost to the average unit cost over all the products

2. Measures

Formulas in measures are conceptually different from anything in Excel because the formula will be evaluated many times using a different context for each evaluation. It can be challenging to anticipate the layout of the PivotTables in which the formula will eventually be evaluated.

Sample Formula	**Comments**
=SUM(FactSales[SalesAmount])	simple aggregation can always be sliced
=CALCULATE(SUM(FactSales[SalesAmount]), DimChannel[ChannelName]="Store")	set context, then evaluate expression
=CALCULATE([Sales], DimChannel[ChannelName]="Store")	set context, then evaluate measure that is a simple aggregation
= [Sales] (DimChannel[ChannelName]="Store")	Shorthand for CALCULATE (measure)
=[Sales] - CALCULATE([Sales],PREVIOUSYEAR(DimDate[DateKey]))	Growth of [Sales] from last year
=[Sales] - [Sales] (PREVIOUSYEAR(DimDate[DateKey]))	Same calc using shorthand syntax
=[Sales]/[Sales] (ALL(DimProduct))	ratio to sales of all products
=TOTALQTD([Sales],DimDate[Datekey])	QTD Sales
=SUMX(VALUES(DimStore[StoreKey]), SUMX(VALUES(DimProduct[ProductKey]), CALCULATE(SUM(FactInventory[OnHandQuantity]), LASTNONBLANK(DATESBETWEEN(DimDate[Datekey],BLANK(),MAX(DimDate[Datekey])), CALCULATE(SUM(FactInventory[OnHandQuantity]))))))	nested aggregation across store and product to find inventory qty based on last inventory taken for period up through current context