First Look: Optimizing SQL Performance with InterSystems Products

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InterSystems IRIS Data Platform Version 2019.1 2019-05-29

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First Look: Optimizing SQL Performance with InterSystems Products

This First Look guide introduces you to InterSystems SQL query optimization, including the use of query analysis tools, several indexing methods, and the ability to review runtime statistics over time.

To browse all of the First Looks, including others that can be performed on a free cloud instance or web instance, see InterSystems First Looks.

1 Query Optimization with InterSystems SQL

InterSystems IRIS offers a full suite of tools for SQL query performance tuning:

- Graphical displays for query plan analysis
- Indexing strategies such as bitmap and bitslice indexing that are compact and can be processed efficiently by vectorized CPU instructions. Each type of index offers benefits for certain query types, such as logical conditions, counting, and aggregate functions. With indexing, you can achieve query performance results of up to billions of rows per second on one core.
- Metrics on SQL query performance over time

Important: The query performance numbers shown in the demos below are representative of multiple trials of the demos on a single Windows 10 laptop. You may see different query performance numbers depending on your environment.

2 Demo: Showing and Interpreting a Query Plan Before Optimization

2.1 Before you Begin

This First Look is best experienced after reading and working through *First Look: InterSystems SQL*. Here you will use the InterSystems IRIS SQL Shell again; the data you will use comes from the million-record table of stock transaction data you created when you worked through the demos in that First Look.

You will also run the `TuneTable` utility, which examines the data in the table and creates statistics used by the *InterSystems SQL query optimizer* (the engine that decides how best to run any query). These statistics include the size of the table (extent size) and the number of unique values per column (selectivity). The optimizer uses table size in scenarios like determining join order, where it's best to start with the smaller table. Selectivity helps the optimizer choose the best index in the case where a table has multiple indices. In a production instance, you normally run `TuneTable` only once: after data is loaded into a table and before you go live.

First Look: InterSystems SQL explains how to take the following steps required to run the demo in that First Look and the one here:

- Select an InterSystems IRIS instance. Your choices include several types of licensed and free evaluation instances; for information on how to deploy each type, see Deploying InterSystems IRIS in *InterSystems IRIS Basics: Connecting an IDE*.
- Open the InterSystems Terminal (Terminal for short) to run the SQL Shell.
- Obtain utility files for this guide from the GitHub repo https://github.com/intersystems/FirstLook-SQLBasics, including
  - stock_table_demo_two.csv, which contains a million rows of stock table data
  - Loader.xml, a class file that contains a utility method to load the data from stock_table_demo_two.csv into an InterSystems IRIS table

2.2 Running the TuneTable Utility

If your InterSystems IRIS instance no longer includes the **`StockTableDemoTwo`** table, recreate and load it by following the first four steps in Demo: Using Bitmap Indexing To Maximize Query Performance (stop before executing the `SELECT DISTINCT` query).

In the SQL Shell, run the `TuneTable` utility on the **`FirstLook.StockTableDemoTwo`** as follows:

```
OBJ DO $SYSTEM.SQL.TuneTable("FirstLook.StockTableDemoTwo")
```

This command generates no visible output in the SQL Shell.

2.3 Using the EXPLAIN Keyword to Show a Query Plan

This demo assumes that you want to obtain the average price for all “SELL” transactions. Given that the table contains a million rows, the needed query could potentially be very slow.

While you may already want to proceed with creating indices on the `Price` and `TransactionType` fields, it will be instructive to see the query plan before you begin optimization work. In the SQL Shell, you can show a plan for a query by prepending the `EXPLAIN` keyword to it. The query plan shows how the SQL query optimizer will use indices, if any, or whether it will read the table data directly to execute the statements.

To use the `EXPLAIN` keyword to show a query plan, execute the following statement in the SQL Shell:

```
EXPLAIN SELECT AVG(Price) As AveragePrice FROM FirstLook.StockTableDemoTwo
     WHERE TransactionType = 'SELL'
```

This will return the query plan, formatted as XML. You’ll see that the code generated to execute a SQL query is divided into *modules*, each of which performs a distinct part of the execution plan, such as evaluating a subquery:

```
Plan
"<plans>
 <plan>
 <sql>
 SELECT AVG ( Price ) As AveragePrice FROM FirstLook . StockTableDemoTwo
     WHERE TransactionType = ?
 </sql>
 <cost value=""13225000""/>
 <module name=""FIRST"" top=""0"">
 Call module B.
 <module name=""D"" top=""0"">
 Output the row.
 </module>
 </module>
 <module name=""B"" top=""1"">
 Read master map FirstLook.StockTableDemoTwo.IDKEY, looping on ID.
 For each row:
     <module name=""C"" top=""0"">
     </module>
```

```
     Accumulate the count(Price).
     Accumulate the sum(Price).
 </module>
 </plan>
</plans>"
```

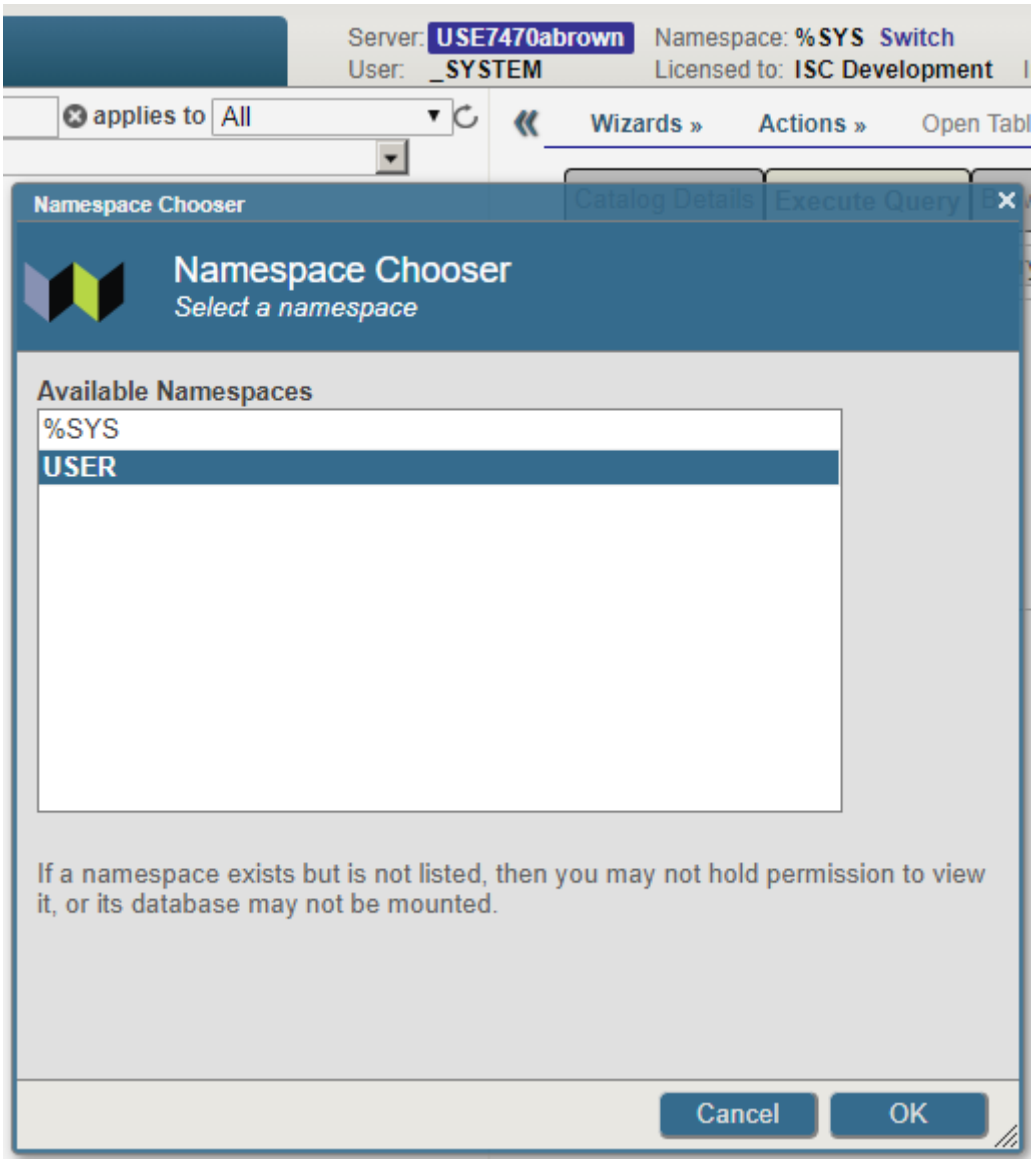
In "Spotting Potential Performance Issues in Query Plan Results", you'll learn to recognize the problems with this query.

2.4 Using the SQL Query Interface in the Management Portal to Show a Query Plan

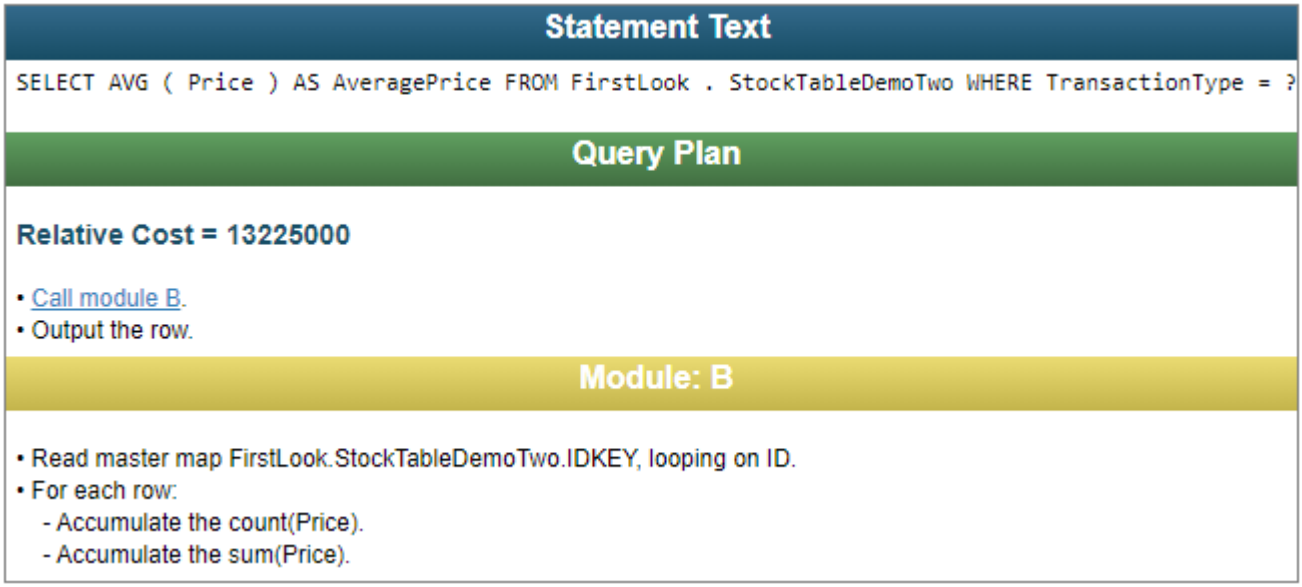
InterSystems IRIS offers a web-based interface in the Management Portal for SQL query execution and plan analysis.

To show a query plan using the SQL query interface in the Management Portal:

1. Open the Management Portal for your instance in your browser, using the URL described for your instance in *InterSystems IRIS Basics: Connecting an IDE*.
2. Make sure you are in the **USER** namespace. If you are not already there:
   - In the top panel of the screen, click **SWITCH** to the right of the name of the current namespace.
   - In the popup, choose **USER** and click **OK**.



3. Navigate to SQL page (**System Explorer** > **SQL**).
4. Omitting the `EXPLAIN` keyword, paste the query from "Using the EXPLAIN Keyword to Show a Query Plan" into the text field in the **Execute Query** tab.
5. Click **Show Plan** to display a query plan. The results will look much like this:



Interpreting these results is the subject of the next section.

2.5 Spotting Potential Performance Issues in Query Plan Results

Both of the query analysis methods described above indicate that there are some serious potential performance issues with this query.

Relative cost can be a good predictor of performance. As the name of this field indicates, this is not an absolute number: it has a meaning relative only to a particular query or a set of queries that differ from each other only in small ways, such as the addition or removal of logical conditions. But if you look at two plans for the same query, and one's relative cost is much lower than the other, it's likely that the plan with the lower cost will be much faster.

Next, the first task in the query plan is "read master map". What this means is that the InterSystems SQL query optimizer will not use any indices to run the query; instead, the data in the table will be read directly. Especially in the case of a large table, this result indicates a query that will not perform well.

As we optimize the query, you'll see its relative cost decrease, and the query plan will change significantly as well.

2.6 Testing Query Execution

To get some actual data as to how the unoptimized query will perform, run it in the SQL Shell:

```
SELECT AVG(Price) As AveragePrice FROM FirstLook.StockTableDemoTwo
   WHERE TransactionType = 'SELL'
   GO
```

The output will look something like this:

```
AveragePrice
266.1595139195757844

1 Rows(s) Affected
statement prepare time(s)/globals/lines/disk: 0.0709s/44496/224048/0ms
          execute time(s)/globals/lines/disk: 0.6040s/1000013/10001138/0ms
                        cached query class: %sqlcq.USER.cls80
```

Statement preparation and execution metrics are listed separately. Take special notice of two items:

- Execution time was 0.604 seconds. While this does not seem like a very long time, it can be vastly improved with the use of indices.

- The number of globals read in the execution step was 1,000,013. (Globals are multidimensional sparse arrays used by InterSystems IRIS to store data; for more information, see the "Introduction to Globals" chapter of *Introduction to InterSystems IRIS Programming*.) To improve query performance, this number should be decreased. You'll see that happen in the next section.

Important: Preparation is done only once: the first time a query is planned anew. Queries are automatically be replanned if a relevant table is modified or if an index is added or removed. Most applications will prepare a query only once, but will execute it many times. So our focus in this demo will be on *tuning execution performance*.

3 Demo: Testing Query Optimizations

3.1 Adding a Bitslice Index to the Price Field

If your query will include aggregate functions on one or more fields, adding a bitslice index to one or more of those fields may improve performance.

A bitslice index represents each numeric data value in a field as a binary bit string, with a bitmap for each digit in the binary value to record which rows have a 1 for that binary digit.

Since we want to get the average price for all "SELL" transactions, it makes sense to add a bitslice index to the `Price` field. To create the bitslice index `PriceIdx` on the `Price` field, execute the following statement in the SQL Shell:

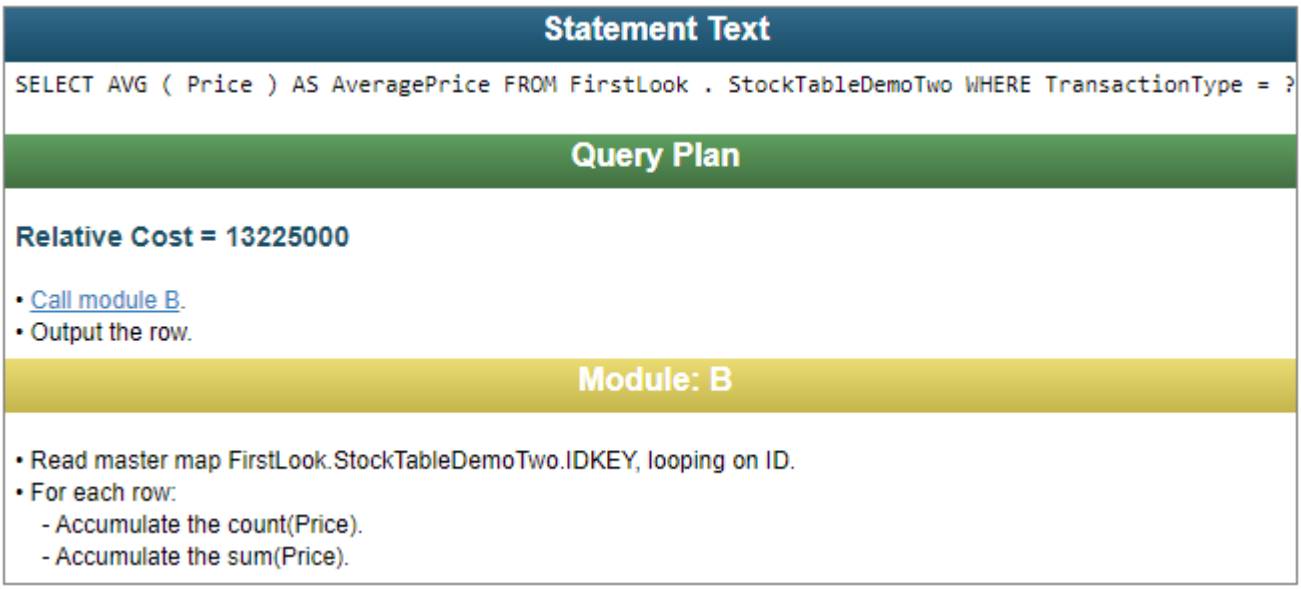
```
CREATE BITSLICE INDEX PriceIdx ON TABLE FirstLook.StockTableDemoTwo (Price)

2.      CREATE BITSLICE INDEX PriceIdx ON TABLE FirstLook.StockTableDemoTwo (Price)

0 Rows Affected
statement prepare time(s)/globals/lines/disk: 0.0411s/1773/13460/28ms
          execute time(s)/globals/lines/disk: 2.0492s/2089760/56804368/152ms
                          cached query class: %sqlcq.USER.cls1
```

Just because you've created the index does not necessarily mean that the InterSystems SQL query optimizer will use it, however, as you'll see below.

3.2 Testing the Effects of the Bitslice Index

To see if the new bitslice index makes any difference in how the query will be executed, or how fast it runs, use either method described above (the SQL Shell or the Management Portal) to show the query plan.

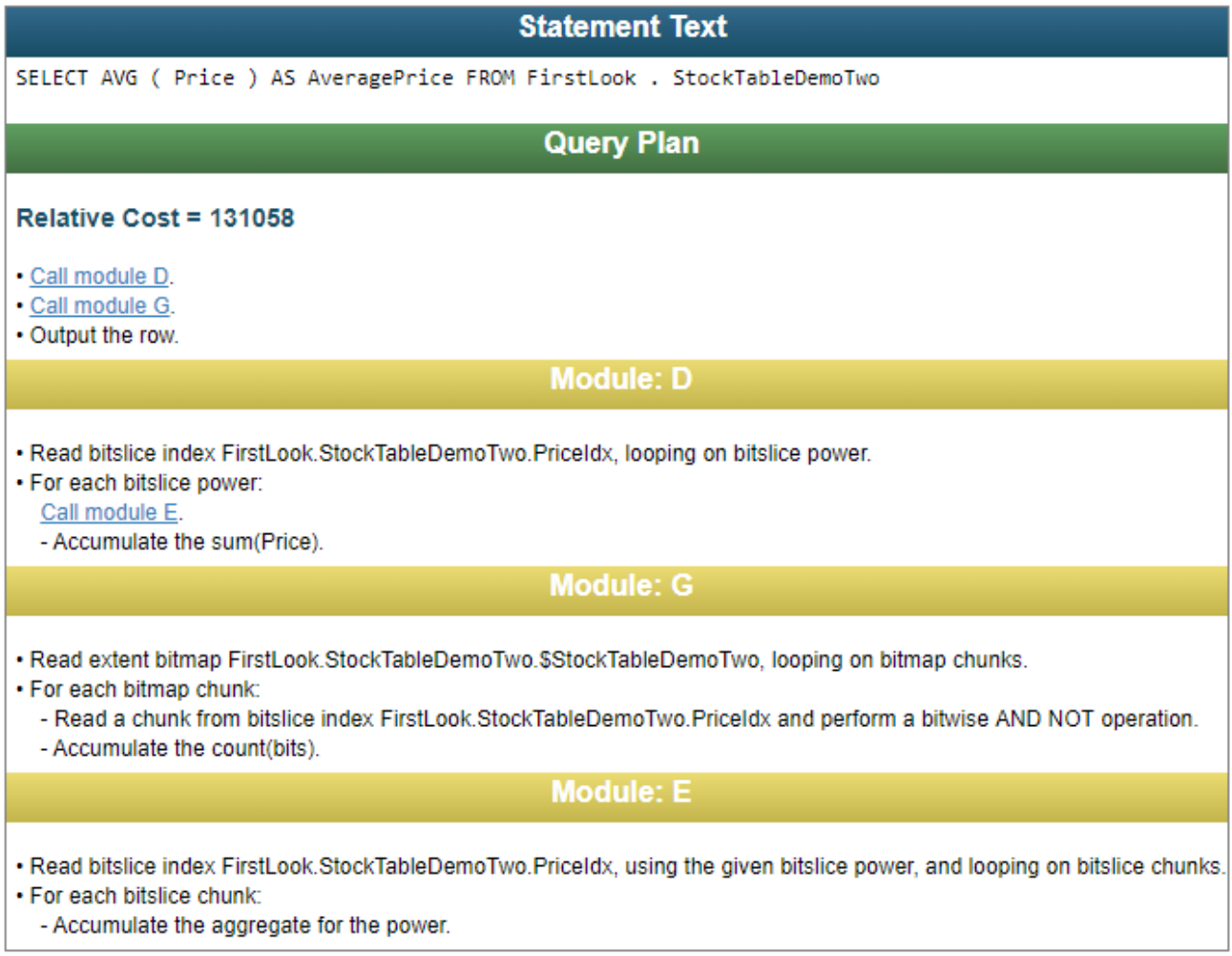
As you'll see, the InterSystems SQL query optimizer will not use the new index:



Running the query yields nearly the same performance statistics as it did before you created the bitslice index (0.6 seconds of execution time compared with 0.604). InterSystems IRIS intelligently caches query plans and data, so subsequent runs of the same query may result in improved performance, as may have been the case here given the slight difference in query performance times. Other applications running on the machine can affect performance as well.

```
        SELECT AVG(Price) As AveragePrice FROM FirstLook.StockTableDemoTwo
        WHERE TransactionType = 'SELL'
        GO

3.      SELECT AVG(Price) As AveragePrice FROM FirstLook.StockTableDemoTwo
        WHERE TransactionType = 'SELL'

AveragePrice
266.1595139195757844

1 Rows(s) Affected

statement prepare time(s)/globals/lines/disk: 0.0929s/44517/217330/31ms
          execute time(s)/globals/lines/disk: 0.5986s/1000023/10001138/0ms
                          cached query class: %sqlcq.USER.cls80
```

If you remove the `WHERE` clause from the query, you'll see quite a different result when you show the query plan:



As you can see, the bitslice index is read as the first step of the query plan. The “master map” is not read in this plan.

The SQL query optimizer also uses a second index, `FirstLook.StockTableDemoTwo.$StockTableDemoTwo`. This is a *bitmap extent index*, which is automatically created whenever the `CREATE TABLE` SQL statement is executed. It is a bitmap index of all the rows in the table, not just one field, and the value of each bit reflects whether or not the row actually exists.

The relative cost of this query, 131058, is much smaller than that of the query that contains the `WHERE` clause. This is because the InterSystems SQL query optimizer employs the bitslice index as the first step of the process (Module D in the plan shown above).

However, the query that we truly want to run contains a `WHERE` clause. So we’ll have to find a way to get the SQL query optimizer to use the index when the `WHERE` clause is present.

3.3 Adding a Bitmap Index To the TransactionType Field

If you read the InterSystems SQL Optimization Guide, you’ll find that the InterSystems SQL query optimizer will often use a bitslice index when it is combined with a bitmap index on the field in a `WHERE` clause.

This is because aggregate queries without the `WHERE` clause can simply aggregate all the data in the index. However, to aggregate only the rows that satisfy a `WHERE` condition, a query must *mask* those bits out of the bitslice index for rows that do not satisfy the condition. A bitmap index on the field in the `WHERE` clause allows this mask to be constructed efficiently.

Fortunately, the other field in the query, `TransactionType`, is a good candidate for a bitmap index because its count of possible values is two (“SELL” and “BUY”).

To add a bitmap index to the `TransactionType` field, execute the following statement in the SQL Shell:

```
CREATE BITMAP INDEX TransactionTypeIdx ON TABLE FirstLook.StockTableDemoTwo
        (TransactionType)

4.      CREATE BITMAP INDEX TransactionTypeIdx ON TABLE FirstLook.StockTableDemoTwo
        (TransactionType)

0 Rows Affected
statement prepare time(s)/globals/lines/disk: 0.0055s/1723/16154/0ms
          execute time(s)/globals/lines/disk: 1.2694s/2074505/20576628/0ms
                        cached query class: %sqlcq.USER.cls1
```

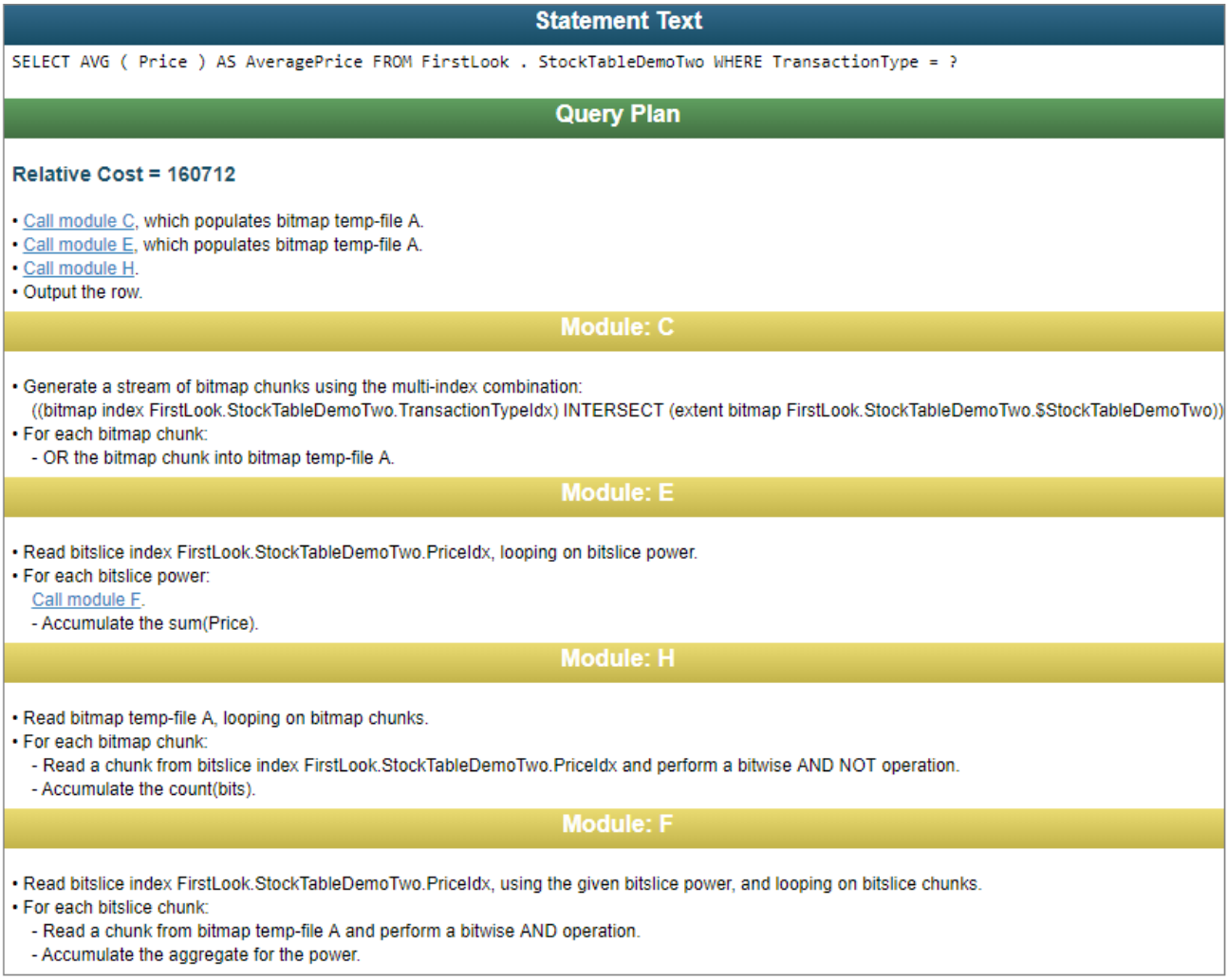
3.4 Retesting Query Performance

Now that you have added bitslice and bitmap indices: if you show the query plan for

```
SELECT AVG(Price) as AveragePrice FROM FirstLook.StockTableDemoTwo
     WHERE TransactionType = 'SELL'
```

in SQL Shell or in the Management Portal, you'll see that the query optimizer uses the two indices you created to obtain the best performance.

Note as well that the relative cost is nearly 90 percent less than that of the unoptimized query, whose cost was 13225000.



Finally, if you run the query in SQL Shell, you'll see a much more efficient use of globals (610 as opposed to 1000013).

Most critically: in this test, the indexed query ran nearly 150 times faster than the unindexed query: 0.0042 seconds of execution time as opposed to 0.604.

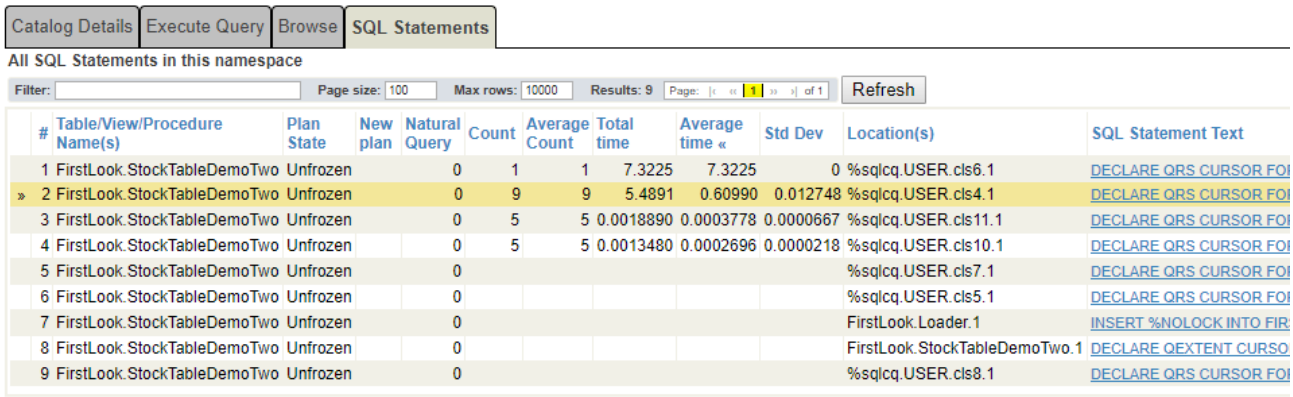
```
        1>>SELECT AVG(Price) As AveragePrice FROM FirstLook.StockTableDemoTwo
        2>>WHERE TransactionType = 'SELL'
        3>>GO

5.      SELECT AVG(Price) As AveragePrice FROM FirstLook.StockTableDemoTwo
         WHERE TransactionType = 'SELL'

AveragePrice
266.1595139195757844

1 Rows(s) Affected

statement prepare time(s)/globals/lines/disk: 0.0879s/45817/243223/9ms
          execute time(s)/globals/lines/disk: 0.0042s/610/2933/0ms
                        cached query class: %sqlcq.USER.cls7
```

To track the performance of the query over time, InterSystems IRIS provides query statistics, which you'll learn how to view in the next section.

4 Viewing Query Performance Over Time

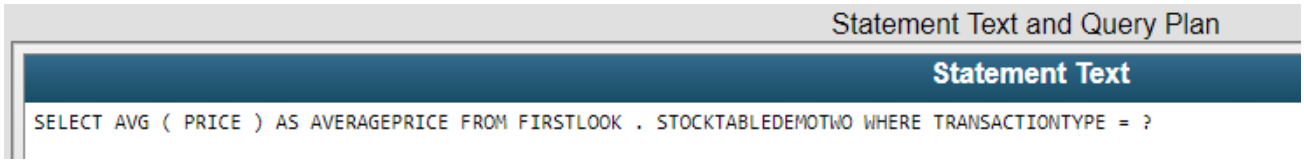
To track down slow-running queries or see how a new query is doing in production, you can use the **SQL Statistics** view in the Management Portal. To navigate to this view, open the SQL query interface in the Management Portal and click **SQL Statistics**.

If, for example, the query you tuned above ran nine times under its original (unoptimized) plan, you might see something like this when you sort on the **Average time** column:



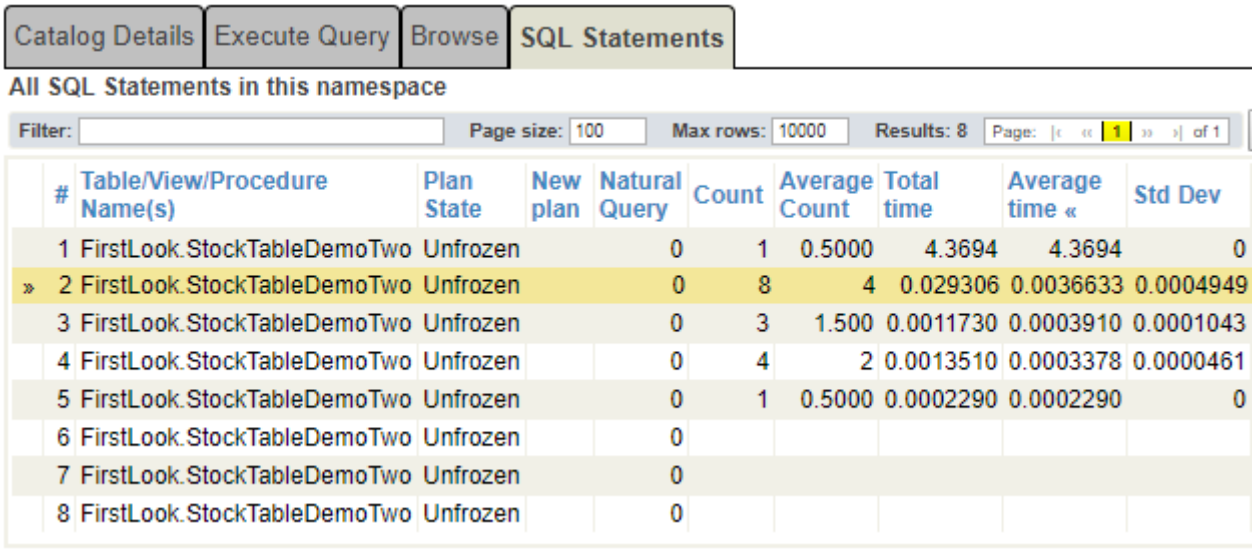
#	Table/View/Procedure Name(s)	Plan State	New plan	Natural Query	Count	Average Count	Total time	Average time «	Std Dev	Location(s)	SQL Statement Text
1	FirstLook.StockTableDemoTwo	Unfrozen		0	1	1	7.3225	7.3225	0	%sqlcq.USER.cls6.1	DECLARE QRS CURSOR FOI
» 2	FirstLook.StockTableDemoTwo	Unfrozen		0	9	9	5.4891	0.60990	0.012748	%sqlcq.USER.cls4.1	DECLARE QRS CURSOR FOI
3	FirstLook.StockTableDemoTwo	Unfrozen		0	5	5	0.0018890	0.0003778	0.0000667	%sqlcq.USER.cls11.1	DECLARE QRS CURSOR FOI
4	FirstLook.StockTableDemoTwo	Unfrozen		0	5	5	0.0013480	0.0002696	0.0000218	%sqlcq.USER.cls10.1	DECLARE QRS CURSOR FOI
5	FirstLook.StockTableDemoTwo	Unfrozen		0						%sqlcq.USER.cls7.1	DECLARE QRS CURSOR FOI
6	FirstLook.StockTableDemoTwo	Unfrozen		0						%sqlcq.USER.cls5.1	DECLARE QRS CURSOR FOI
7	FirstLook.StockTableDemoTwo	Unfrozen		0						FirstLook.Loader.1	INSERT %NOLOCK INTO FIR
8	FirstLook.StockTableDemoTwo	Unfrozen		0						FirstLook.StockTableDemoTwo.1	DECLARE QEXTENT CURSO
9	FirstLook.StockTableDemoTwo	Unfrozen		0						%sqlcq.USER.cls8.1	DECLARE QRS CURSOR FOI

Clicking on the statement's link in the **SQL Statement Text column** allows you to view the query in SQL form:



You can also tie SQL statement execution to the **SQL Statistics** view using the name of the cached query class, which is the last line of output in the SQL Shell and is listed in the **Location(s)** column of **SQL Statistics**.

After you optimize the query and run it a few times, you can expect to see improvements in the **Total time** and **Average time** columns.


Catalog Details | Execute Query | Browse | SQL Statements

All SQL Statements in this namespace

Filter: Page size: 100 Max rows: 10000 Results: 8 Page: 1 of 1

#	Table/View/Procedure Name(s)	Plan State	New plan	Natural Query	Count	Average Count	Total time	Average time «	Std Dev
1	FirstLook.StockTableDemoTwo	Unfrozen		0	1	0.5000	4.3694	4.3694	0
» 2	FirstLook.StockTableDemoTwo	Unfrozen		0	8	4	0.029306	0.0036633	0.0004949
3	FirstLook.StockTableDemoTwo	Unfrozen		0	3	1.500	0.0011730	0.0003910	0.0001043
4	FirstLook.StockTableDemoTwo	Unfrozen		0	4	2	0.0013510	0.0003378	0.0000461
5	FirstLook.StockTableDemoTwo	Unfrozen		0	1	0.5000	0.0002290	0.0002290	0
6	FirstLook.StockTableDemoTwo	Unfrozen		0					
7	FirstLook.StockTableDemoTwo	Unfrozen		0					
8	FirstLook.StockTableDemoTwo	Unfrozen		0					

Note that the value of **Count** has dropped. This is because the addition of the bitmap and bitslice indices caused the query plan to change, which in turn triggered a removal of cached queries for the associated class. The query has run under the new query plan a total of eight times, four times on average per day.

5 Learn More About InterSystems SQL

To learn more about SQL and InterSystems IRIS, see:

5.1 Introductory Material

- First Look: InterSystems SQL
- Using InterSystems SQL
- InterSystems SQL Reference
- InterSystems IRIS SQL Overview
- SQL Resource Guide – 2017

5.2 SQL Development

- SQL – Things You Should Know
- Learn InterSystems SQL: Design and Execution
- Developing with InterSystems Objects and SQL

5.3 Query Optimization

- InterSystems SQL Optimization Guide
- Academy – Optimizing SQL Performance
- Optimizing SQL Queries

- Learn InterSystems SQL: Performance

5.4 Sharding and Scalability

- First Look: Scaling for Data Volume with Sharding
- Scalability Guide
- We Want More! – Solving Scalability

5.5 SQL Search

- First Look: SQL Search with InterSystems IRIS
- Using InterSystems SQL Search
- Creating iFind Indices for Searching Text Fields

5.6 JDBC

- First Look: JDBC and InterSystems IRIS
- Using Java JDBC with InterSystems IRIS (documentation)
- Java Overview
- Using JDBC with InterSystems IRIS (online learning)