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ESTABLISHING AND SETTING THRESHOLDS FOR AN SQL SERVER ENVIRONMENT

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SUMMARY

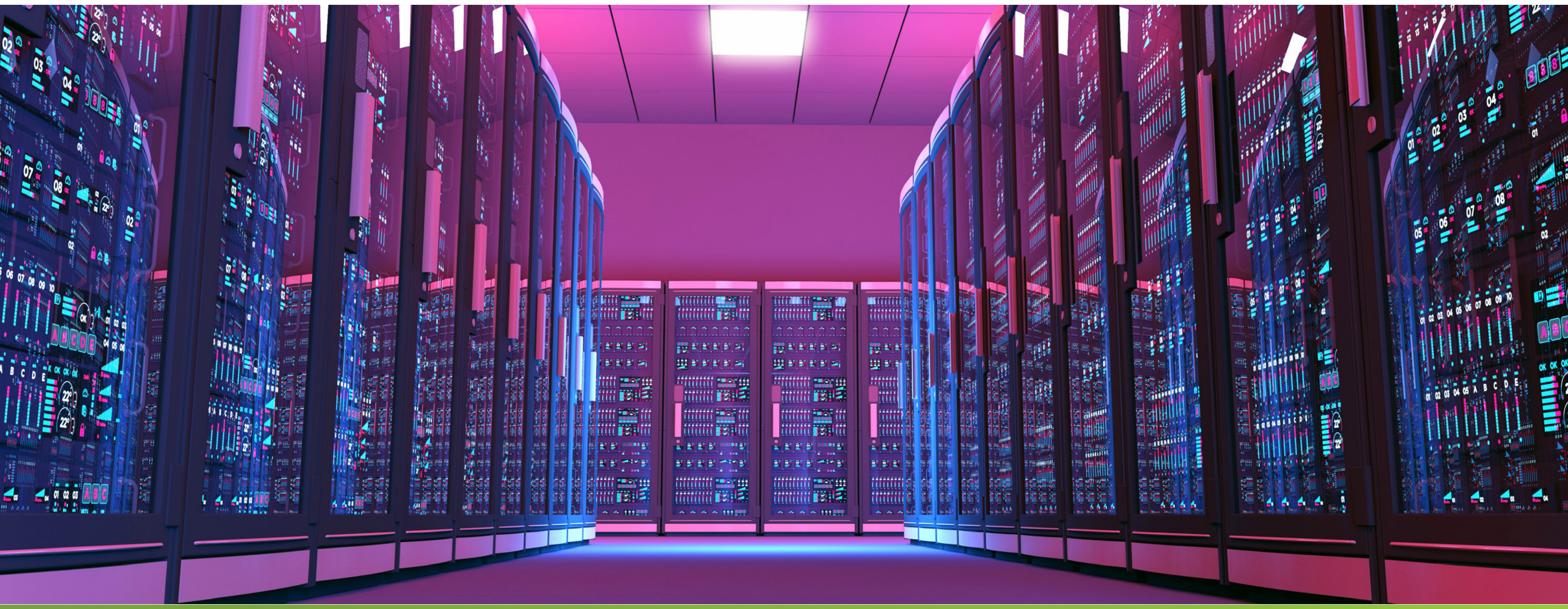
This white paper is a guide for DBAs about determining the proper thresholds for monitoring a SQL Server environment.

Monitoring SQL Server is a critical component of the job of a database administrator (DBA). The bigger the environment is, the more important monitoring becomes. Enterprise environments have a high ratio of servers to DBAs and no DBA can keep watch of every aspect of the environment on their own. A very important aspect of monitoring is alerting.

Monitoring alone is not enough. When certain resource metrics or counters are reached, the DBA needs to be alerted and, sometimes, notified fast that we have reached the threshold. Alerts can be delivered in a variety of ways and should not be confused with notifications. Alerts can be written to a log, raised in an application interface, or sent to another system for processing. A notification is a response to an alert that informs a person, or a group of people, that a specific alert has been raised.

Monitoring, alerts, and notifications all work together to form a good monitoring solution. Any good monitoring tool will perform these three basic functions. An additional function that is not part of all monitoring tools is baselining. Baselining is important for effective monitoring, as most metrics or counters can differ from system to system.

There are only a handful of counters that can state a specific value shows a problem. Most counters have to be watched over time to establish an acceptable threshold for a healthy system. A baseline is a continual process. You cannot just baseline once. As systems develop, so will their performance profiles. So a great monitoring tool will have a built-in baselining functionality.



WHY WE BASELINE

To have a sound approach to troubleshooting is a lot like the methodologies used by a doctor. Many people take the approach of offering potential solutions without knowing what the core problem is, hoping that it fixes it. Imagine telling your doctor that you had a sore throat. And he gave you an assortment of pills, telling you to take the blue ones today. And if you do not feel better, take the red ones the following day. You would go to a different doctor… one that would figure out what was wrong with you and treat it.

What is the first thing they do in the office of the doctor when you see a doctor for the first time? They check your vital signs. They get your weight, height, blood pressure, pulse, temperature, and so on. Then, when you come back on subsequent events, they check it again. Why do they do this?

The doctor is doing a lot more than just trying to justify the high cost of a doctor's visit. They are getting a baseline of your health and then they validate that baseline to see how your health is changing. This baseline and check system may help them discover health issues that you are not even aware of yet. My blood pressure was a little higher than normal, but not enough to be concerned, when I saw my doctor for a stomach flu. The slight elevation was because of my illness. If the next time I go, it is even higher or remains higher without the illness, then the doctor might get concerned. Therefore they advise you to do regular physicals.

"So many times, all we hear are complaints that something is slow. How do you fix a problem like "slow"? You need to know what is performing differently when it is slow as compared to how it runs."

A regular physical will tell what my vital signs look like when I am healthy and no extenuating circumstances affect the numbers. Body temperature is a great statistic to use here. The normal temperature for a person is considered being 98.6 degrees Fahrenheit (37.0 degrees Celsius). In actuality, the normal temperature is between 97 to 100 degrees Fahrenheit (36.1 to 37.8 degrees Celsius), according to "The Physician's Factbook". So if I am at the high end of the scale, and I come in with a temperature of 100 degrees, would the doctor say that I have a fever or not? Unless he is done with a baseline, he would have no way of knowing if I was normal or running high. He'd look at past visits and physicals, if there were any, to see how I compared.

You need to do the same thing with your SQL Servers. So many times, all we hear are complaints that something is slow. How do you fix a problem like "slow"? You need to know what is performing differently when it is slow as compared to how it runs. I do not have enough fingers and toes to count how many things exist can cause SQL Server to run slow. Heck, I would need more hands just to count the things that could make disk I/O slow.

When somebody says that their SQL Server is running slow, I will ask, “What has changed?” They talk about code changes when I really want to know what measurable statistic differs from normal. If someone says that full scans/second is high, I will ask what the normal scan rate is. The answer is, “I do not know.” If you do not know what the normal scan rate is, how do you know it is high? When someone asks me about a specific counter, it is because they read somewhere that the counter should not be above a certain level. Lots of posts out there will tell you that full scans/second should be 0. That would be nice, but it is not realistic. I would be alarmed if the scan rate on one of my servers was 0 because that would mean that no users could hit the server.

For many performance counters, there is no definitive value that will show a problem. Know what the counter looks like when it is healthy to know when it is not healthy. If I have a baseline for reference, I can compare the current metrics with metrics from the day before, the week before, or some other time. There may even be times when I may want to compare it to much older baselines if there is some quarterly or annual event occurring. For example, if I managed a SQL Server that powered a retail website and we were in the holiday shopping season, I may want to compare the current performance to the metrics from one year ago.

HOW TO BASELINE

There are several tools you can use to help you baseline. There are several third-party applications that will monitor your SQL Server, raise alerts, and send notifications for critical alerts. When selecting these tools, I consider built-in performance baselining a key feature. It is the easiest and fastest way to implement baselining.

If you are the do-it-yourself type or do not have a budget for one of these tools, you can implement some basic baselining with built-in Windows and SQL Server tools. Windows Performance Monitor (PerfMon) is a tool every DBA should know how to use. To set up a PerfMon collection is pretty straightforward. We can use it as your baseline collection tool, but does not provide any mechanism for raising alerts or sending notifications. It is only a small piece of the puzzle.

SQL Server can raise alerts and send notifications. If you are doing it on your own, you will need to write your own process to check the performance counters and take the appropriate action if a threshold is crossed. The Dynamic Management View (DMV) sys.dm_os_performance_counters has the counters you will need to monitor SQL Server. You can poll the counters at regular intervals, check for metrics that exceed your defined thresholds and take action.

SQL Server has a built-in alerting system, but it has limited applicability. To raise alerts and send notifications for all the performance metrics you want, you will need to query the DMV noted above. SQL Server also has the management data warehouse (MDW), which has built-in collectors you can use to capture performance data from multiple servers and collect in a central store. The MDW comes with stock reports that can view the performance information. It could be a useful part of baselining and historical reporting on performance, but we do not collect it at a high frequency and does not raise alerts or send notifications. Also, if you choose to build alerting and notifications off of the MDW database, it will require custom coding.

ESTABLISHING AND SETTING THRESHOLDS

Whatever method you decide to use for monitoring, baselining, and alerting, the tricky part is establishing and setting thresholds for the alerts. For many counters, this means using baselines to determine thresholds to set for your counters. Even the counters that have recommended standard thresholds often require tweaking to adjust to differences in the system. The important thing is to identify what the counters look like when the server is healthy, and at what point the counters show an unhealthy server.

Described below are the counters that I find important to monitor and baseline, and are helpful when troubleshooting general server performance. Where plausible, I have provided thresholds for warning and critical alerts for the counters.

DISK COUNTERS

One question I hear sometimes is whether it is better to monitor logical disk counters or physical disk counters. Except for free space counters (percent and megabyte) in the logical disk group, you get the same set of counters with both sets. The key difference between them is in how the disks are grouped. If you isolate disks at the physical level, then each physical disk also represents a complete logical disk. It is common, however, to place the C drive (system) and D drive (SQL install drive) on the same logical disk. If the C and D drive are partitions of the same physical drive, they will be the same physical drive but separate logical drives.

When you have logical drives sharing the same physical drive, you will want to know the counters at both the logical and physical level. If the disks are isolated, then either counter set will return the same data. In such a case, I prefer physical disk counters as we label them by drive letter rather than drive number.

Below you will find the disk counters I find useful and how I set thresholds for them. For the sake of brevity, I list physical disk counters only, but these also apply to logical disk counters.

- \Avg. Disk sec/Read: Average time spent for each read. A constant high number in this metric may show a slow disk system or a steady, heavy workload. Spikes in this metric may represent a disk system insufficient for sudden heavy loads.
    - Warning threshold of 10 ms.
    - Critical threshold of 20 ms.
    - We may adjust this counter based on acceptable values determined through baselining.
- \Avg. Disk sec/Write: Average time spent for each write. A constant high number in this metric may show a slow disk system or a steady, heavy workload. Spikes in this metric may represent a disk system insufficient for sudden heavy loads.
    - Warning threshold of 10 ms.
    - Critical threshold of 20 ms.
    - We may adjust this counter based on acceptable values determined through baselining.
- \Disk Reads/sec: Average disk reads per second. I do not alert on this counter. I use it to gain more information when one of the per/second counters was high, had spiked, or changed.
    - This counter should be baselined and watched for changes.
- \Disk Writes/sec: Average disk writes per second. I do not alert on this counter. I use it to gain more information when one of the per/second counters was high, had spiked, or changed.
    - This counter should be baselined and watched for changes.

- \Avg. Disk Bytes/Read: Average size in bytes of reads. I do not alert on this counter. I use it to gain more information when one of the per/second counters was high, had spiked, or changed.
    - This counter should be baselined and watched for changes.
    - Changes in this counter can represent a change in the workload or may help identify an inefficient read profile.
- \Avg. Disk Bytes/Write: Average size in bytes of writes. I do not alert on this counter. I use it to gain more information when one of the per/second counters was high, had spiked, or changed.
- This counter should be baselined and watched for changes.
- Changes in this counter can represent a change in the workload or may help identify an inefficient read profile.

You may have noticed that we ignored a very popular type of disk metric. There is no mention of the counters related to the disk queue. The reason for this is that the disk queue is very often misleading or misunderstood in modern systems. In order to understand the disk queue metrics, you must know how many actual disks are behind the drive. Most SANs have built-in caching that hide disk queuing from the server-side.

MEMORY OR NON-UNIFORM MEMORY ACCESS (NUMA) NODE MEMORY

A popular memory counter you hear people talk about is Page Faults/sec. We define a page fault as a check in memory for a page that fails and results in a read from disk. However, this is only part of what the counter tells us. It counts both hard page faults (read from disk) and soft page faults (successful read from memory). We measure all SQL Server requests for a read as a page fault. So without more information, the counter is not very useful.

These counters are also available under the NUMA Node Memory counter object. You can measure these counters at individual NUMA nodes on NUMA systems. For production systems under heavy workload, it may be helpful to view these counters at the NUMA level. You may encounter issues where the workload is uneven and one or a few NUMA nodes are under pressure when others are not.

- \Available Mbytes: This counter is also available in bytes and kilobytes. I monitor megabytes because modern servers have a lot of memory. This counter can show memory pressure external to the SQL Server.
    - A good starting point for a warning threshold is 10% of the total memory.
    - A good critical threshold is 5% of total memory.
    - The counter should be baselined and sudden or we should investigate drastic changes in available memory.
- \Pages/sec: This counter should be as low as possible. 0 is the preferable metric for this counter, but it may not always be possible.
    - This counter should be baselined and watched for changes. The baseline can help you determine some thresholds to use for alerting.

NETWORK INTERFACE

We tracked network counters at the Network Interface Card (NIC) level. Below are four counters that I track and baseline for network activity. Each of these counters can vary from one NIC card to another, even within the same machine. It depends on how we use them and for what purpose. Each counter should be baselined and watched for changes. These counters describe the amount of activity in each NIC card.

- \Bytes Received/sec
- \Bytes Sent/sec
- \Packets Received/sec
- \Packets Sent/sec

I monitor for packets that get discarded and packets that generate an error. Both counters may show that packets are being dropped and should be 0. Numbers greater than 0 may show pressure on the NIC because of top activity (discards) or problems with the NIC or network (errors). I baseline these values, but only use them when connection issues are reported and I need to determine if there are issues at the NIC level.

- \Packets Received Discarded
- \Packets Received Errors
- \Packets Outbound Discarded
- \Packets Outbound Errors

PROCESSOR

Processors keep getting more complex with NUMA architectures (non-uniform memory access) and hyper-threading. Yet the way we monitor processor usage has remained relatively the same. We just need to know how busy it is and raise alerts when it gets above a certain level.

- \Avg % Processor Time: This is the percentage of time that the processors are busy. I monitor this counter per processor and the total counter. I alert only on the total counter, as one or a few busy processors on a server with many processors may not show a problem. Baselining should always include individual processors.
  - Warning threshold is 75%
  - Critical threshold is 90%
  - This counter should also be baselined and watched for changes. We may adjust thresholds based on baselined values.
- \Peak % Processor Time: This is the highest usage that the processor experienced for the specified interval. This can be indicative that the processor usage is having very high, very short spikes in activity. This counter gives you an idea of how high the usage went. I do not alert to this counter and only refer to it when investigating a potential processor bottleneck.

SQL SERVER COUNTERS

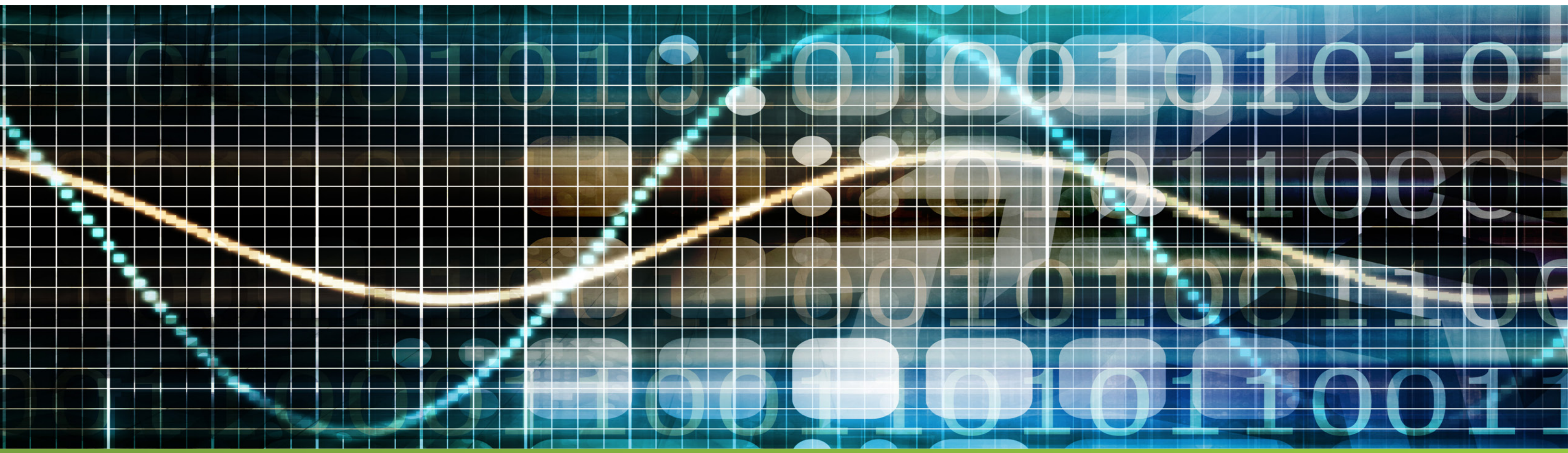
- SQLServer:Access Methods
  - \Worktables Created/Sec: Work tables are special areas in the tempdb space that are used to store temporary results such as spools, large object (Max, XML) variables, and cursors. This will vary, and I rarely alert on this counter. Baseline this counter and watch for changes. I may also investigate this counter when tempdb activity is very high.
    - We can set thresholds after a consistent baseline is collected, but I rarely set alerts for this.
  - \Workfiles Created/Sec: Work files are special areas in the tempdb space that are used to store temporary results, such as hash joins and hash aggregates. This will vary, and I rarely alert on this counter. Baseline this counter and watch for changes. I may also investigate this counter when tempdb activity is very high.
    - We can set thresholds after a consistent baseline is collected, but I rarely set alerts for this.
  - \Full Scans/Sec: Full scans can be a major indicator of performance health, but the counter will vary widely by system. There is no way to determine from the counter if the scans are large or small. A scan of a 10 row table and a scan of a 10 million row table both count as 1 scan.
    - Thresholds should be determined by collecting a baseline to identify a healthy scan count

        - Sudden changes in this counter may or may not show a problem, but it warrants further investigation to determine if it does. It might be a change in workload that is not a problem for the system.
        - Use the DMV sys.dm_db_index_usage_stats to determine which indexes and tables are experiencing top levels of scans. This could show that we need additional indexing to ease large scans, or that the scans are not a problem.
    - \Page Splits/Sec: Page splits, like page faults, is another tricky counter. We count all new allocations of pages as a page split, even if splitting an existing page is not required. As a result, this number can be high even in a healthy system.
    - Baseline this counter and watch for changes.
    - If further investigation is warranted, Extended Events can determine if the page splits are correct page splits or just page allocations.
- SQLServer Buffer Manager\Buffer Cache Hit Ratio: Buffer cache hit ratio is the ratio of reads read from the buffer cache divided by the total number of read attempts. You want this counter to be as close to 100 (percent) as possible, but a system can deviate from this a bit for short periods of time and still be quite healthy.
    - Warning threshold is 80%.
    - Critical threshold is 60%.
    - Baseline and watch for drastic dips in this counter.
- SQLServer Buffer Node\Page Life Expectancy: Page life expectancy (PLE) is a counter that is often misunderstood. There is a lot of information out there about specific numbers for these counters. Those recommendations are outdated.

  A PLE of 300 is an old recommendation that no longer makes sense. This was a good metric to alert on when SQL Servers had minimal amounts of memory. The number you should use today varies based on many factors, including the amount of memory available.

  We can also see this counter under Buffer Manager, but that counter represents the PLE as a whole. Most modern servers have a NUMA architecture, each node having the local memory to itself. Under Buffer Manager, the PLE of each NUMA node is added and then divided by the number of nodes to get the average PLE of the server. Buffer Node provides PLE per NUMA node and allows to identify when there is one or a few NUMA nodes experiencing problems that might otherwise go undetected.

  PLE is the estimated time in seconds that a page that does not get reused will stay in memory. Baseline this metric and determine what the proper thresholds for your system are when it is healthy.



- SQLServer Plan Cache\Cache Pages: This is the section size of the buffer pool reserved for execution plans. This counter can vary from system to system, and I do not alert on it. Sudden changes can show a memory pressure or a change in the workload.
    - Baseline this counter and watch for sudden dips or spikes.
- SQLServer SQLStatistics\Batch Requests/Sec: Batch requests per second shows the amount of work the SQL Server is doing. It is used to find out what a server can do during stress tests. Outside stress testing, it is also used to track how hard the SQL Server is working. The counter alone does not represent a problem, but it is used to identify if the workload has changed when investigating other issues.
    - Baseline this counter and watch for changes.
- SQLServer Databases\Transactions/Sec: Transactions per second shows the amount of work the SQL Server is doing. It is used to find out what a server can do during stress tests. Outside stress testing, it is also used to track how hard the SQL Server is working. The counter alone does not represent a problem, but it is used to identify if the workload has changed when investigating other issues.
    - Baseline this counter and watch for changes.
- SQLServer General Statistics: The temp table counters can vary from server to server, from workload to workload, and even from one time of the day to another. These counters represent how quickly temp tables are being created and destroyed, as well as the number of active temp tables that are in use at a specified time. These counters alone do not show a problem; however, they can be useful when investigating heavy tempdb usage. Use these counters to determine the root cause of tempdb load when it is under pressure. These counters correlate to usage of temp tables and table.
- variables in SQL code.
    - \Active Temp Tables
    - \Temp Table Creation Rate
    - \Temp Tables For Destruction

CONCLUSION

To decide to move SQL Server to a virtual platform the first time can be a nervous time, but it does not need to be. With proper planning and best practices to guide you, it is pretty straightforward to have a successful migration to virtual machines. You can use the methods laid out in this paper to wade into virtualization with noncritical workloads and small footprint servers before moving on to considering critical production workloads.

You can move the SQL Server to a virtual platform with ease using these guidelines. Do not make the same common mistakes that others have made. Use the best practices outlined here to guide you and help you avoid these pitfalls. The licensing information provided should make the complex licensing rules a lot clearer and help you make the right licensing decisions for virtualizing the SQL Server.

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