

# Analysis Report

**spmv\_kernel(float volatile \*, int volatile \*, int const \*, float const \*, int, float\*)**

Duration	178.914 $\mu$ s
Grid Size	[ 2016,1,1 ]
Block Size	[ 256,1,1 ]
Registers/Thread	32
Shared Memory/Block	1 KiB
Shared Memory Requested	64 KiB
Shared Memory Executed	64 KiB
Shared Memory Bank Size	4 B

## [1] Tesla P100-SXM2-16GB

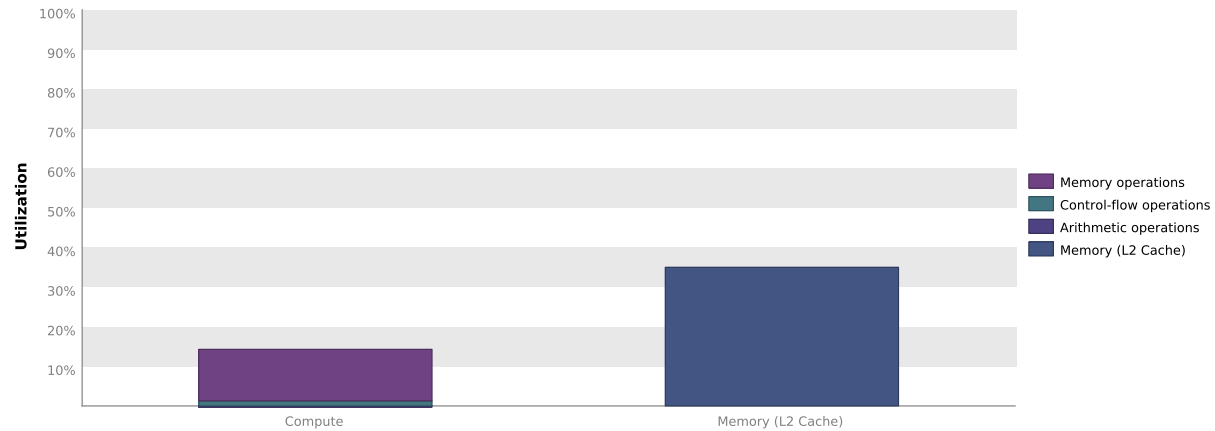
GPU UUID	GPU-f2fce699-dee4-1480-f496-25390926c253
Compute Capability	6.0
Max. Threads per Block	1024
Max. Threads per Multiprocessor	2048
Max. Shared Memory per Block	48 KiB
Max. Shared Memory per Multiprocessor	64 KiB
Max. Registers per Block	65536
Max. Registers per Multiprocessor	65536
Max. Grid Dimensions	[ 2147483647, 65535, 65535 ]
Max. Block Dimensions	[ 1024, 1024, 64 ]
Max. Warps per Multiprocessor	64
Max. Blocks per Multiprocessor	32
Half Precision FLOP/s	10.612 TeraFLOP/s
Single Precision FLOP/s	10.612 TeraFLOP/s
Double Precision FLOP/s	5.306 TeraFLOP/s
Number of Multiprocessors	56
Multiprocessor Clock Rate	1.48 GHz
Concurrent Kernel	true
Max IPC	3
Threads per Warp	32
Global Memory Bandwidth	732.16 GB/s
Global Memory Size	15.895 GiB
Constant Memory Size	64 KiB
L2 Cache Size	4 MiB
Memcpy Engines	3
PCIe Generation	3
PCIe Link Rate	8 Gbit/s
PCIe Link Width	16

## 1. Compute, Bandwidth, or Latency Bound

The first step in analyzing an individual kernel is to determine if the performance of the kernel is bounded by computation, memory bandwidth, or instruction/memory latency. The results below indicate that the performance of kernel "spmv\_kernel" is most likely limited by instruction and memory latency. You should first examine the information in the "Instruction And Memory Latency" section to determine how it is limiting performance.

### 1.1. Kernel Performance Is Bound By Instruction And Memory Latency

This kernel exhibits low compute throughput and memory bandwidth utilization relative to the peak performance of "Tesla P100-SXM2-16GB". These utilization levels indicate that the performance of the kernel is most likely limited by the latency of arithmetic or memory operations. Achieved compute throughput and/or memory bandwidth below 60% of peak typically indicates latency issues.



## 2. Instruction and Memory Latency

Instruction and memory latency limit the performance of a kernel when the GPU does not have enough work to keep busy. The results below indicate that the GPU does not have enough work because instruction execution is stalling excessively.

### 2.1. Kernel Profile - PC Sampling

The Kernel Profile - PC Sampling gives the number of samples for each source and assembly line with various stall reasons. Using this information you can pinpoint portions of your kernel that are introducing latencies and the reason for the latency. Samples are taken in round robin order for all active warps at a fixed number of cycles regardless of whether the warp is issuing an instruction or not.

Instruction Issued - Warp was issued

Instruction Fetch - The next assembly instruction has not yet been fetched.

Execution Dependency - An input required by the instruction is not yet available. Execution dependency stalls can potentially be reduced by increasing instruction-level parallelism.

Memory Dependency - A load/store cannot be made because the required resources are not available or are fully utilized, or too many requests of a given type are outstanding. Data request stalls can potentially be reduced by optimizing memory alignment and access patterns.

Texture - The texture sub-system is fully utilized or has too many outstanding requests.

Synchronization - The warp is blocked at a `__syncthreads()` call.

Constant - A constant load is blocked due to a miss in the constants cache.

Pipe Busy - The compute resource(s) required by the instruction is not yet available.

Memory Throttle - Large number of pending memory operations prevent further forward progress. These can be reduced by combining several memory transactions into one.

Not Selected - Warp was ready to issue, but some other warp issued instead. You may be able to sacrifice occupancy without impacting latency hiding and doing so may help improve cache hit rates.

Other - The warp is blocked for an uncommon reason.

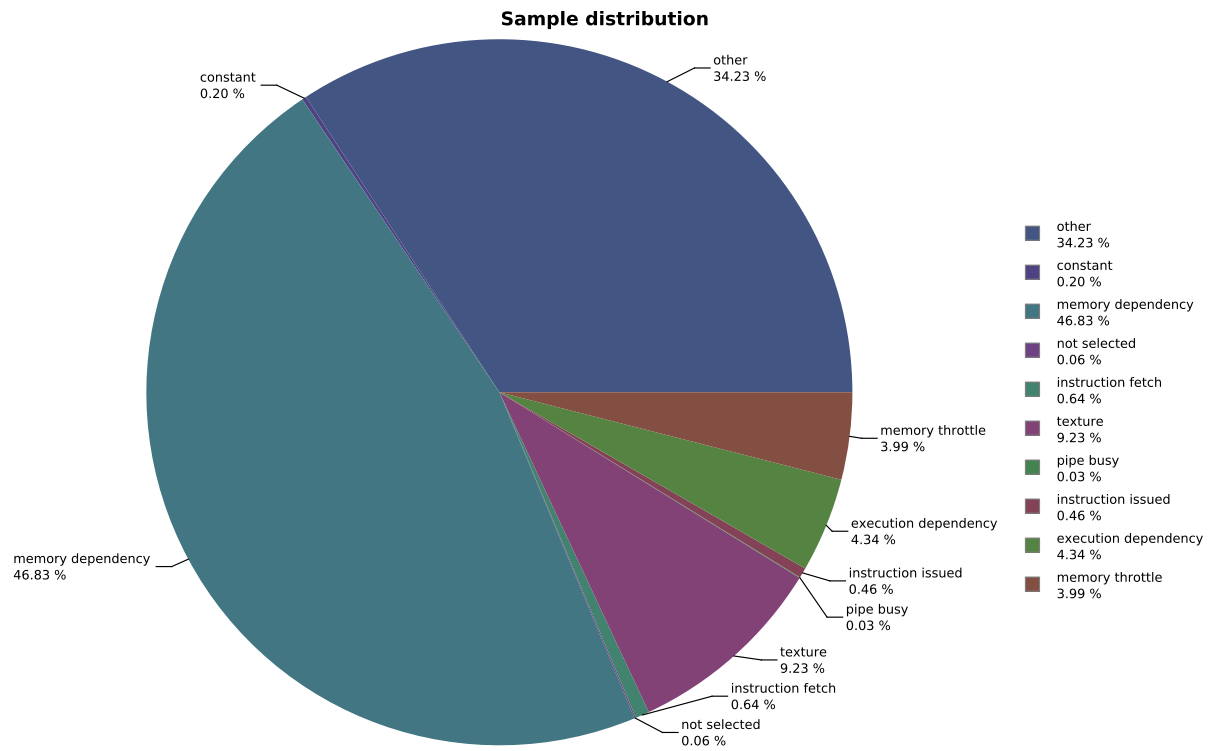
Sleeping - The warp is blocked, yielded or sleeping.

*Examine portions of the kernel that have high number of samples to know where the maximum time was spent and observe the latency reasons for those samples to identify optimization opportunities.*

Cuda Functions	Sample Count	% of Kernel Samples
<code>spmv_kernel(float volatile *, int volatile *, int const *, float const *, int, float*)</code>	23482	100.0

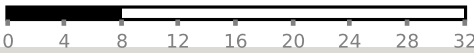


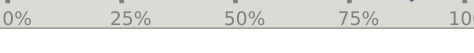


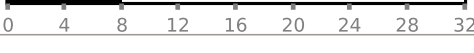
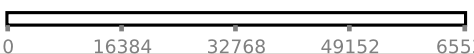




#### Source Files :

<code>/g/g92/lin32/project/DataPlacement/PORPLE/OrgAndOptBenchmarks/spmv/7.cu</code>
<code>/usr/tce/packages/cuda/cuda-9.0.176/bin/./targets/ppc64le-linux/include/texture_fetch_functions.h</code>



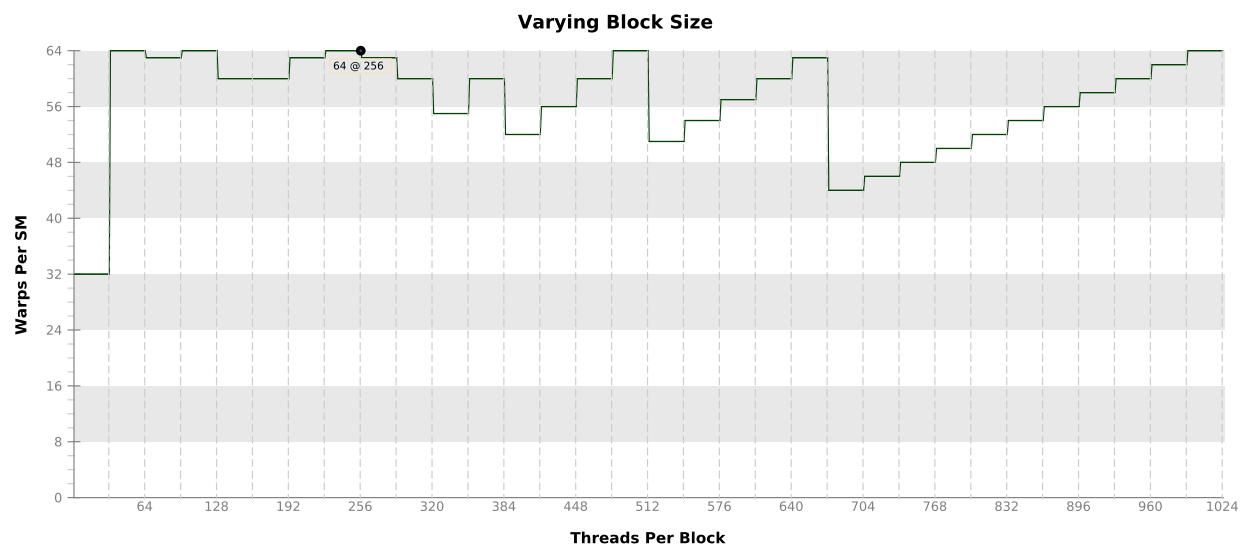
## 2.2. Occupancy Is Not Limiting Kernel Performance

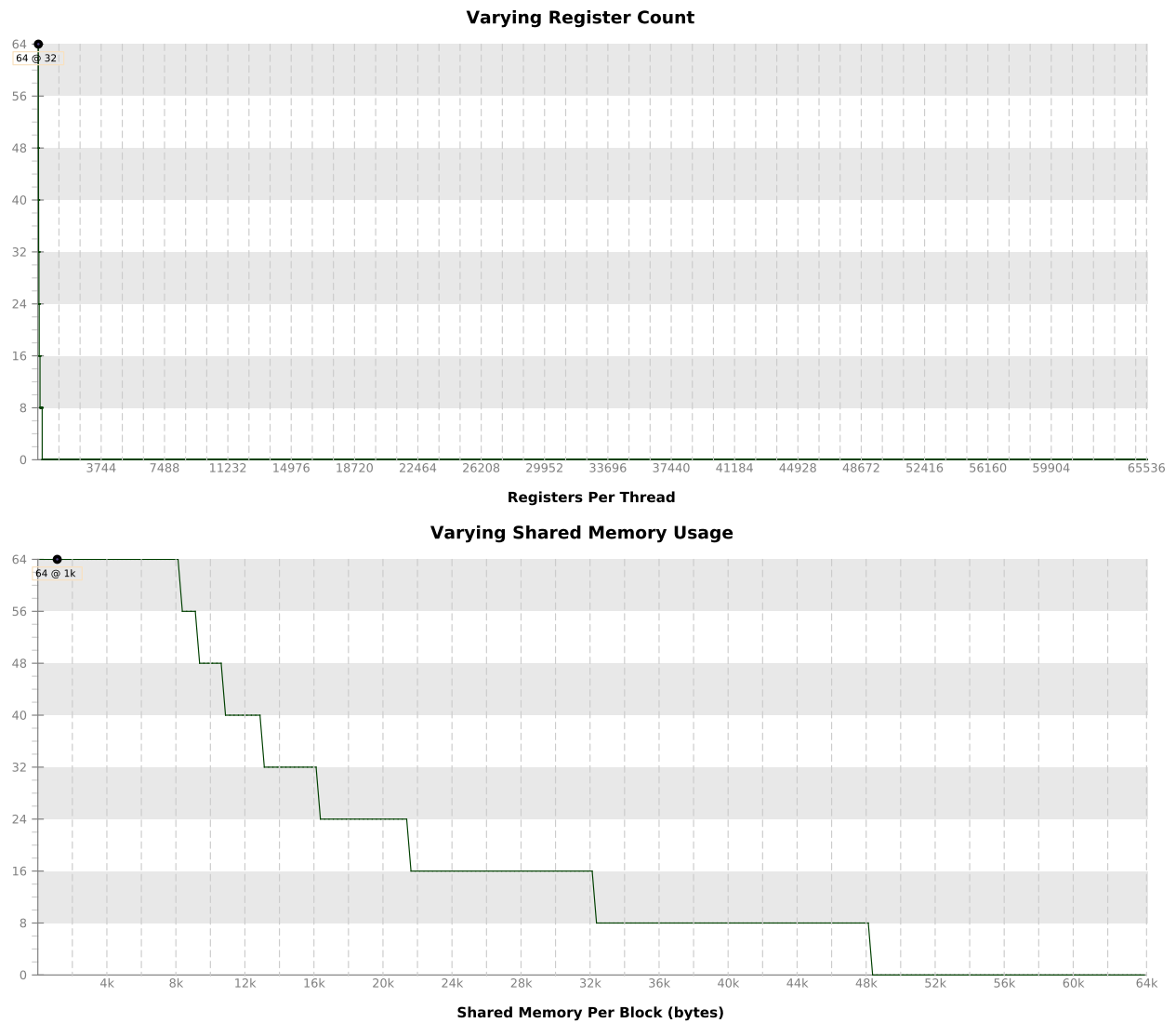
The kernel's block size, register usage, and shared memory usage allow it to fully utilize all warps on the GPU.

Variable	Achieved	Theoretical	Device Limit	Grid Size: [ 2016,1,1 ] (2016 blocks) Block Size: [ 256,1,1 ]
Occupancy Per SM				
Active Blocks		8	32	
Active Warps	56.22	64	64	
Active Threads		2048	2048	
Occupancy	87.8%	100%	100%	
Warps				
Threads/Block		256	1024	
Warps/Block		8	32	
Block Limit		8	32	
Registers				
Registers/Thread		32	65536	
Registers/Block		8192	65536	
Block Limit		8	32	
Shared Memory				
Shared Memory/Block		1024	65536	
Block Limit		64	32	

## 2.3. Occupancy Charts

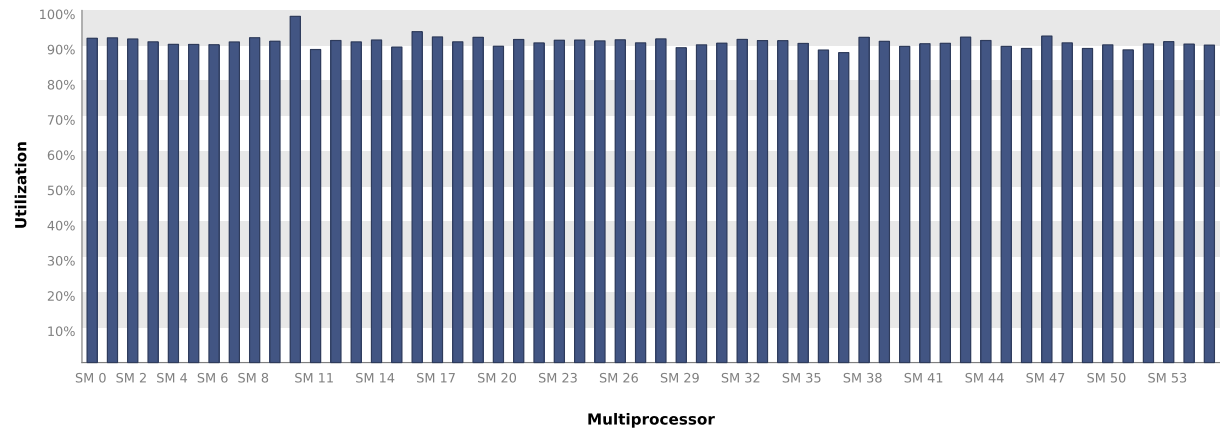
The following charts show how varying different components of the kernel will impact theoretical occupancy.





## 2.4. Multiprocessor Utilization

The kernel's blocks are distributed across the GPU's multiprocessors for execution. Depending on the number of blocks and the execution duration of each block some multiprocessors may be more highly utilized than others during execution of the kernel. The following chart shows the utilization of each multiprocessor during execution of the kernel.



### 3. Compute Resources

GPU compute resources limit the performance of a kernel when those resources are insufficient or poorly utilized. Compute resources are used most efficiently when all threads in a warp have the same branching and predication behavior. The results below indicate that a significant fraction of the available compute performance is being wasted because branch and predication behavior is differing for threads within a warp.

#### 3.1. Kernel Profile - Instruction Execution

The Kernel Profile - Instruction Execution shows the execution count, inactive threads, and predicated threads for each source and assembly line of the kernel. Using this information you can pinpoint portions of your kernel that are making inefficient use of compute resource due to divergence and predication.

*Examine portions of the kernel that have high execution counts and inactive or predicated threads to identify optimization opportunities.*

Cuda Functions :

```
spmv_kernel(float volatile *, int volatile *, int const *, float const *, int, float*)
```

Maximum instruction execution count in assembly: 33014

Average instruction execution count in assembly: 9265

Instructions executed for the kernel: 2779766

Thread instructions executed for the kernel: 81108603

Non-predicated thread instructions executed for the kernel: 68734067

Warp non-predicated execution efficiency of the kernel: 77.3%

Warp execution efficiency of the kernel: 91.2%

Source files :

```
/g/g92/lin32/project/DataPlacement/PORPLE/OrgAndOptBenchmarks/spmv/7.cu
```

```
/usr/tce/packages/cuda/cuda-9.0.176/bin/./targets/ppc64le-linux/include/texture_fetch_functions.h
```

#### 3.2. Low Warp Execution Efficiency

Warp execution efficiency is the average percentage of active threads in each executed warp. Increasing warp execution efficiency will increase utilization of the GPU's compute resources. The kernel's warp execution efficiency of 77.8% is less than 100% due to divergent branches and predicated instructions. If predicated instructions are not taken into account the warp execution efficiency for these kernels is 91.4%.

*Optimization: Reduce the amount of intra-warp divergence and predication in the kernel.*

#### 3.3. Divergent Branches

Compute resource are used most efficiently when all threads in a warp have the same branching behavior. When this does not occur the branch is said to be divergent. Divergent branches lower warp execution efficiency which leads to inefficient use of the GPU's compute resources.

*Optimization: Each entry below points to a divergent branch within the kernel. For each branch reduce the amount of intra-warp divergence.*

**/g/g92/lin32/project/DataPlacement/PORPLE/OrgAndOptBenchmarks/spmv/7.cu**

Line 167	Divergence = 0% [ 0 divergent executions out of 16128 total executions ]
Line 172	Divergence = 0% [ 0 divergent executions out of 8 total executions ]
Line 172	Divergence = 2.3% [ 751 divergent executions out of 33014 total executions ]
Line 189	Divergence = 100% [ 16128 divergent executions out of 16128 total executions ]
Line 197	Divergence = 0% [ 0 divergent executions out of 16128 total executions ]

#### 3.4. Function Unit Utilization



Different types of instructions are executed on different function units within each SM. Performance can be limited if a function unit is over-used by the instructions executed by the kernel. The following results show that the kernel's performance is not limited by overuse of any function unit.

Load/Store - Load and store instructions for shared and constant memory.

Texture - Load and store instructions for local, global, and texture memory.

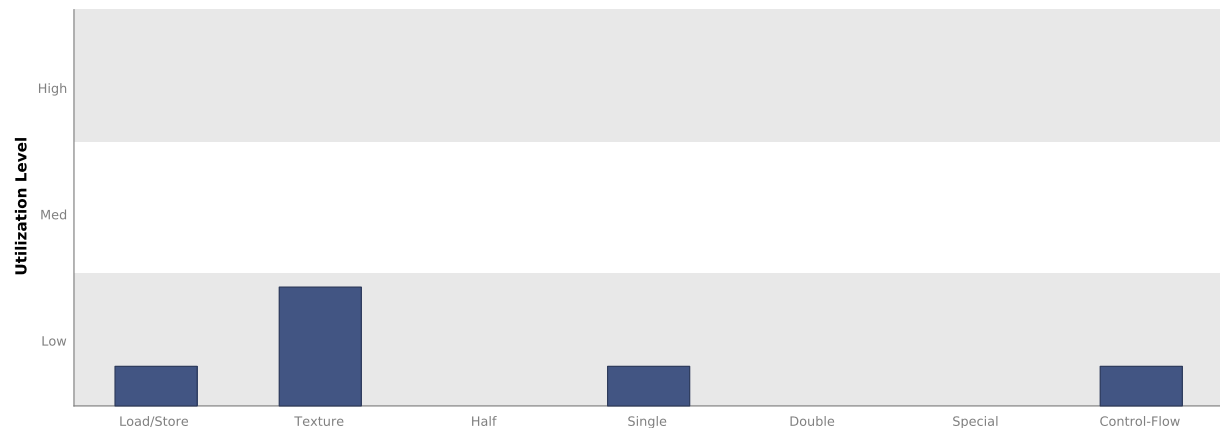
Half - Half-precision floating-point arithmetic instructions.

Single - Single-precision integer and floating-point arithmetic instructions.

Double - Double-precision floating-point arithmetic instructions.

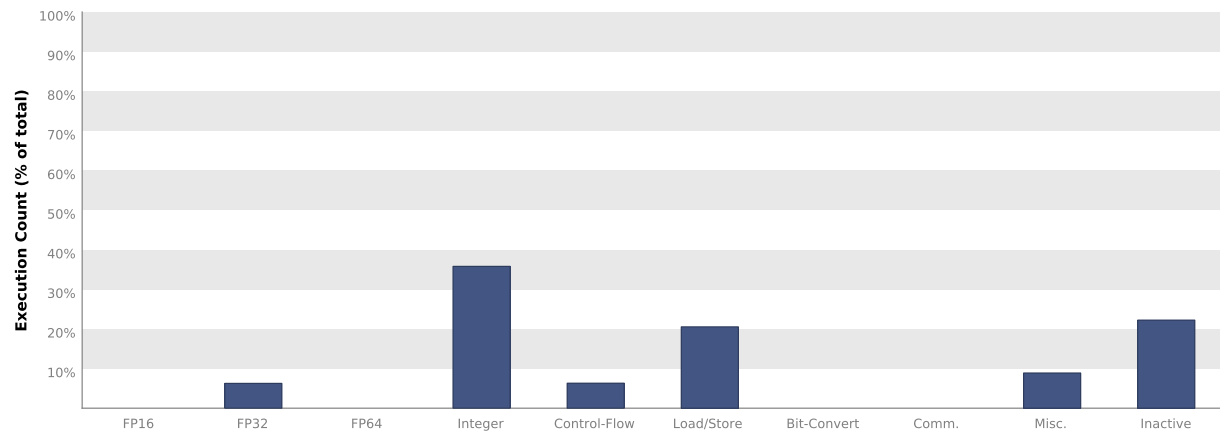
Special - Special arithmetic instructions such as sin, cos, popc, etc.

Control-Flow - Direct and indirect branches, jumps, and calls.



### 3.5. Instruction Execution Counts

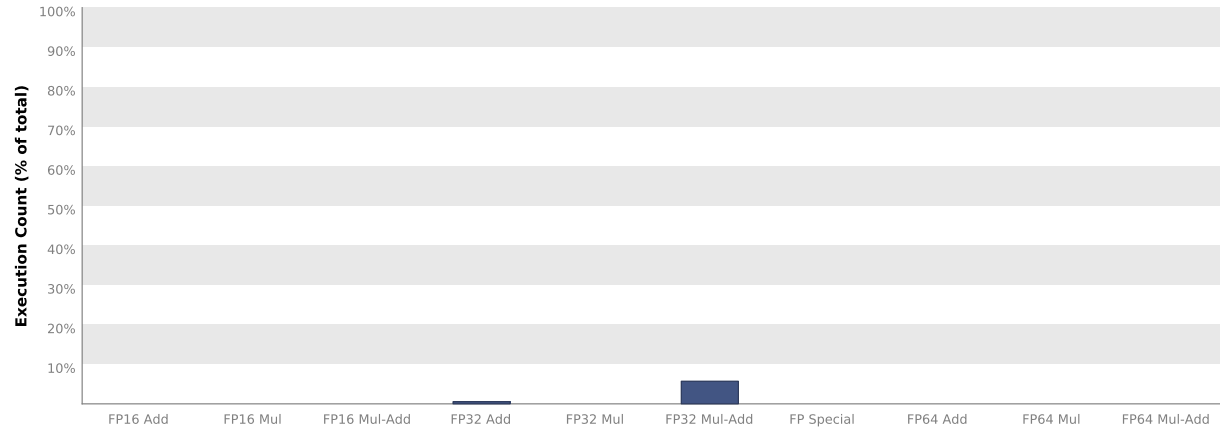
The following chart shows the mix of instructions executed by the kernel. The instructions are grouped into classes and for each class the chart shows the percentage of thread execution cycles that were devoted to executing instructions in that class. The "Inactive" result shows the thread executions that did not execute any instruction because the thread was predicated or inactive due to divergence.



### 3.6. Floating-Point Operation Counts

The following chart shows the mix of floating-point operations executed by the kernel. The operations are grouped into classes and

for each class the chart shows the percentage of thread execution cycles that were devoted to executing operations in that class. The results do not sum to 100% because non-floating-point operations executed by the kernel are not shown in this chart.



## 4. Memory Bandwidth

Memory bandwidth limits the performance of a kernel when one or more memories in the GPU cannot provide data at the rate requested by the kernel.

### 4.1. Memory Bandwidth And Utilization

The following table shows the memory bandwidth used by this kernel for the various types of memory on the device. The table also shows the utilization of each memory type relative to the maximum throughput supported by the memory.

Transactions	Bandwidth	Utilization	
Shared Memory			
Shared Loads	177408	129.943 GB/s	
Shared Stores	96768	70.878 GB/s	
Shared Total	274176	200.821 GB/s	
L2 Cache			
Reads	5617137	1,028.574 GB/s	
Writes	16141	2.956 GB/s	
Total	5633278	1,031.529 GB/s	
Unified Cache			
Local Loads	0	0 B/s	
Local Stores	0	0 B/s	
Global Loads	3511030	319.238 GB/s	
Global Stores	16128	2.953 GB/s	
Texture Reads	2766784	506.636 GB/s	
Unified Total	6293942	828.827 GB/s	
Device Memory			
Reads	1389488	254.434 GB/s	
Writes	18097	3.314 GB/s	
Total	1407585	257.748 GB/s	
System Memory			
[ PCIe configuration: Gen3 x16, 8 Gbit/s ]			
Reads	0	0 B/s	
Writes	5	915.567 kB/s	