



PC gaming processor study: Intel Core i9-9900K processor vs. competitors

(Updated October 12, 2018)

A study commissioned by Intel Corporation

We published the initial version of this report on October 8, 2018 and published this updated version October 12, 2018. The updated report includes test results for AMD Ryzen™ 7 2700X in default mode (i.e., Creator mode). For more detail on the changes from the initial report and this updated report, please review the change log on the final page of this document.

In the Principled Technologies labs, we compared the performance of eight processors on 19 popular games. We compared the following processors:

- 9th Gen Intel® Core™ i9-9900K processor
- 8th Gen Intel® Core™ i7-8700K processor
- 8th Gen Intel® Core™ i7-8086K processor
- Intel® Core™ i9-9980XE Extreme Edition processor
- Intel® Core™ i9-9900X X-series processor
- AMD Ryzen™ 7 2700X processor
- AMD Ryzen™ Threadripper™ 2990WX processor
- AMD Ryzen™ Threadripper™ 2950X processor

The 19 games we tested on each system were:

- Total War™: WARHAMMER® II
- Counter-Strike®: Global Offensive
- Gears of War 4
- War Thunder
- Ashes of the Singularity™
- Forza Motorsport 7
- Assassin's Creed®: Origins
- Far Cry® 5
- World of Warcraft®: Battle for Azeroth™
- Sid Meier's Civilization® VI
- Fortnite
- World of Tanks
- Tom Clancy's Rainbow Six® Siege
- PlayerUnknown's Battlegrounds (PUBG)
- Rise of the Tomb Raider™
- Middle-earth™: Shadow of War™
- Tom Clancy's Ghost Recon®: Wildlands
- Grand Theft Auto V
- Final Fantasy® XV

Continue to the next page for detailed results for Intel processor-based systems and AMD processor-based systems (running in both Game and Creator modes).

The tables below present our results. We used in-game benchmarks where possible; otherwise, we used Fraps™ to record frames per second (FPS).

Total War™: WARHAMMER® II

	Total War™: WARHAMMER® II Battle (FPS)	Performance advantage for Intel® Core™ i9-9900K	Total War™: WARHAMMER® II Campaign (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	110.4		105.6	
Intel® Core™ i7-8700K	109.7	0.6%	99.6	6.0%
Intel® Core™ i7-8086K	109.9	0.5%	99.1	6.6%
Intel® Core™ i9-9980XE	76.1	45.1%	72.8	45.1%
Intel® Core™ i9-9900X	69.5	58.8%	71.7	47.3%
AMD in Game mode				
AMD Ryzen™ 7 2700X	100.7	9.6%	85.0	24.2%
AMD Ryzen™ Threadripper™ 2990WX	95.1	16.1%	79.0	33.7%
AMD Ryzen™ Threadripper™ 2950X	99.6	10.8%	84.8	24.5%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	98.2	12.4%	82.7	27.7%
AMD Ryzen™ Threadripper™ 2990WX	18.2	506.6%	16.7	532.3%
AMD Ryzen™ Threadripper™ 2950X	85.0	29.9%	68.9	53.3%

	Total War:™ WARHAMMER® II Skaven (FPS)	Performance advantage for Intel® Core™ i9-9900K	Total War:™ WARHAMMER® II Laboratory (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	87.4		43.6	
Intel® Core™ i7-8700K	82.9	5.4%	41.1	6.1%
Intel® Core™ i7-8086K	83.1	5.2%	41.3	5.6%
Intel® Core™ i9-9980XE	55.5	57.5%	33.2	31.3%
Intel® Core™ i9-9900X	54.3	61.0%	33.0	32.1%
AMD in Game mode				
AMD Ryzen™ 7 2700X	70.4	24.1%	28.7	51.9%
AMD Ryzen™ Threadripper™ 2990WX	67.4	29.7%	36.5	19.5%
AMD Ryzen™ Threadripper™ 2950X	71.5	22.2%	36.9	18.2%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	70.3	24.3%	37.0	17.8%
AMD Ryzen™ Threadripper™ 2990WX	12.6	593.7%	9.1	379.1%
AMD Ryzen™ Threadripper™ 2950X	60.8	43.8%	33.6	29.8%

Counter-Strike®: Global Offensive

	Counter-Strike®: Global Offensive (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	442.4	
Intel® Core™ i7-8700K	374.4	18.2%
Intel® Core™ i7-8086K	380.8	16.2%
Intel® Core™ i9-9980XE	389.8	13.5%
Intel® Core™ i9-9900X	349.4	26.6%
AMD in Game mode		
AMD Ryzen™ 7 2700X	295.9	49.5%
AMD Ryzen™ Threadripper™ 2990WX	284.0	55.8%
AMD Ryzen™ Threadripper™ 2950X	300.3	47.3%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	298.1	48.4%
AMD Ryzen™ Threadripper™ 2990WX	277.1	59.6%
AMD Ryzen™ Threadripper™ 2950X	280.2	57.9%

Gears of War 4

	Gears of War 4 Overall (FPS)	Performance advantage for Intel® Core™ i9-9900K	Gears of War 4 Average CPU - Game (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	189.2		326.0	
Intel® Core™ i7-8700K	175.9	7.6%	305.4	6.7%
Intel® Core™ i7-8086K	171.2	10.5%	299.6	8.8%
Intel® Core™ i9-9980XE	159.9	18.3%	295.1	10.5%
Intel® Core™ i9-9900X	158.7	19.2%	277.1	17.6%
AMD in Game mode				
AMD Ryzen™ 7 2700X	129.2	46.4%	228.2	42.9%
AMD Ryzen™ Threadripper™ 2990WX	141.8	33.4%	243.1	34.1%
AMD Ryzen™ Threadripper™ 2950X	145.3	30.2%	222.1	46.8%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	151.5	24.9%	256.9	26.9%
AMD Ryzen™ Threadripper™ 2990WX	129.7	45.9%	237.3	37.4%
AMD Ryzen™ Threadripper™ 2950X	126.0	50.2%	214.8	51.8%

	Gears of War 4 Average CPU - Render (FPS)	Performance advantage for Intel® Core™ i9-9900K	Gears of War 4 (GPU bound %)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	193.1		7.4%	
Intel® Core™ i7-8700K	178.0	8.5%	0.9%	722.2%
Intel® Core™ i7-8086K	174.4	10.7%	0.6%	1,133.3%
Intel® Core™ i9-9980XE	167.8	15.1%	5.0%	48.0%
Intel® Core™ i9-9900X	166.1	16.3%	5.1%	45.1%
AMD in Game mode				
AMD Ryzen™ 7 2700X	130.9	47.5%	0.3%	2,366.7%
AMD Ryzen™ Threadripper™ 2990WX	143.4	34.7%	0.7%	957.1%
AMD Ryzen™ Threadripper™ 2950X	148.5	30.0%	3.2%	131.3%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	153.5	25.8%	0.5%	1,380.0%
AMD Ryzen™ Threadripper™ 2990WX	130.8	47.6%	0.3%	2,366.7%
AMD Ryzen™ Threadripper™ 2950X	127.5	51.5%	0.1%	7,300.0%

War Thunder

	War Thunder Tank Battle (FPS)	Performance advantage for Intel® Core™ i9-9900K	War Thunder Tank Battle (Rating)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	149.3		8,536	
Intel® Core™ i7-8700K	139.7	6.9%	7,988	6.9%
Intel® Core™ i7-8086K	136.9	9.1%	7,826	9.1%
Intel® Core™ i9-9980XE	96.1	55.4%	5,492	55.4%
Intel® Core™ i9-9900X	120.9	23.5%	6,912	23.5%
AMD in Game mode				
AMD Ryzen™ 7 2700X	128.0	16.6%	7,315	16.7%
AMD Ryzen™ Threadripper™ 2990WX	116.6	28.0%	6,665	28.1%
AMD Ryzen™ Threadripper™ 2950X	118.7	25.8%	6,784	25.8%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	118.1	26.4%	6,754	26.4%
AMD Ryzen™ Threadripper™ 2990WX	51.0	192.7%	2,913	193.0%
AMD Ryzen™ Threadripper™ 2950X	81.6	83.0%	4,665	83.0%

Ashes of the Singularity™

	Ashes of the Singularity™ Crazy (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	55.8	
Intel® Core™ i7-8700K	50.3	10.9%
Intel® Core™ i7-8086K	49.0	13.9%
Intel® Core™ i9-9980XE	55.5	0.5%
Intel® Core™ i9-9900X	55.2	1.1%
AMD in Game mode		
AMD Ryzen™ 7 2700X	35.5	57.2%
AMD Ryzen™ Threadripper™ 2990WX	44.7	24.8%
AMD Ryzen™ Threadripper™ 2950X	46.0	21.3%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	47.4	17.7%
AMD Ryzen™ Threadripper™ 2990WX	41.7	33.8%
AMD Ryzen™ Threadripper™ 2950X	48.3	15.5%

Forza Motorsport 7

	Forza Motorsport 7 (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	203.6	
Intel® Core™ i7-8700K	194.4	4.7%
Intel® Core™ i7-8086K	200.0	1.8%
Intel® Core™ i9-9980XE	202.8	0.4%
Intel® Core™ i9-9900X	142.0	43.4%
AMD in Game mode		
AMD Ryzen™ 7 2700X	150.9	34.9%
AMD Ryzen™ Threadripper™ 2990WX	156.7	29.9%
AMD Ryzen™ Threadripper™ 2950X	158.9	28.1%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	178.3	14.2%
AMD Ryzen™ Threadripper™ 2990WX	156.6	30.0%
AMD Ryzen™ Threadripper™ 2950X	157.8	29.0%

Assassin's Creed®: Origins

	Assassin's Creed®: Origins (Benchmark score)	Performance advantage for Intel® Core™ i9-9900K	Assassin's Creed®: Origins (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	13,862		119.0	
Intel® Core™ i7-8700K	13,359	3.8%	114.0	4.4%
Intel® Core™ i7-8086K	13,420	3.3%	115.0	3.5%
Intel® Core™ i9-9980XE	13,180	5.2%	108.0	10.2%
Intel® Core™ i9-9900X	12,854	7.8%	108.0	10.2%
AMD in Game mode				
AMD Ryzen™ 7 2700X	10,531	31.6%	84.0	41.7%
AMD Ryzen™ Threadripper™ 2990WX	12,111	14.5%	104.0	14.4%
AMD Ryzen™ Threadripper™ 2950X	12,259	13.1%	105.0	13.3%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	12,354	12.2%	106.0	12.3%
AMD Ryzen™ Threadripper™ 2990WX	11,658	18.9%	98.0	21.4%
AMD Ryzen™ Threadripper™ 2950X	12,663	9.5%	111.0	7.2%

Far Cry® 5

	Far Cry® 5 (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	135.0	
Intel® Core™ i7-8700K	130.0	3.8%
Intel® Core™ i7-8086K	131.0	3.1%
Intel® Core™ i9-9980XE	117.0	15.4%
Intel® Core™ i9-9900X	117.0	15.4%
AMD in Game mode		
AMD Ryzen™ 7 2700X	103.0	31.1%
AMD Ryzen™ Threadripper™ 2990WX	109.0	23.9%
AMD Ryzen™ Threadripper™ 2950X	113.0	19.5%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	113.0	19.5%
AMD Ryzen™ Threadripper™ 2990WX	45.0	200.0%
AMD Ryzen™ Threadripper™ 2950X	95.0	42.1%

World of Warcraft®: Battle for Azeroth™

	World of Warcraft®: Battle for Azeroth™ Vol'dun to Zuldazar Avg (FPS)	Performance advantage for Intel® Core™ i9-9900K	World of Warcraft®: Battle for Azeroth™ Zuldazar to Vol'dun Avg (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	129.2		123.1	
Intel® Core™ i7-8700K	119.8	7.8%	114.6	7.4%
Intel® Core™ i7-8086K	118.8	8.7%	113.5	8.5%
Intel® Core™ i9-9980XE	120.3	7.4%	115.5	6.5%
Intel® Core™ i9-9900X	116.7	10.7%	111.5	10.4%
AMD in Game mode				
AMD Ryzen™ 7 2700X	96.5	33.8%	92.7	32.7%
AMD Ryzen™ Threadripper™ 2990WX	100.3	28.8%	96.0	28.3%
AMD Ryzen™ Threadripper™ 2950X	100.0	29.2%	95.2	29.4%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	99.3	30.1%	94.8	29.8%
AMD Ryzen™ Threadripper™ 2990WX	68.7	88.1%	66.6	84.8%
AMD Ryzen™ Threadripper™ 2950X	82.8	56.0%	80.5	53.0%

Sid Meier's Civilization® VI

	Sid Meier's Civilization® VI AI test: Avg turn duration (sec) (Lower is better)	Performance advantage for Intel® Core™ i9-9900K	Sid Meier's Civilization® VI Graphics test: Frame time (ms) (Lower is better)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	11.86		8.17	
Intel® Core™ i7-8700K	12.55	5.5%	8.88	8.0%
Intel® Core™ i7-8086K	12.57	5.6%	8.80	7.2%
Intel® Core™ i9-9980XE	13.15	9.8%	8.82	7.3%
Intel® Core™ i9-9900X	13.61	12.9%	9.46	13.6%
AMD in Game mode				
AMD Ryzen™ 7 2700X	14.16	16.2%	10.60	22.9%
AMD Ryzen™ Threadripper™ 2990WX	13.29	10.8%	10.33	20.9%
AMD Ryzen™ Threadripper™ 2950X	12.78	7.2%	10.04	18.6%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	13.14	9.7%	9.83	16.9%
AMD Ryzen™ Threadripper™ 2990WX	13.24	10.4%	11.35	28.0%
AMD Ryzen™ Threadripper™ 2950X	12.65	6.2%	11.11	26.5%

Fortnite

	Fortnite New replay mode (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	172.0	
Intel® Core™ i7-8700K	174.1	-1.2%
Intel® Core™ i7-8086K	168.9	1.8%
Intel® Core™ i9-9980XE	162.6	5.8%
Intel® Core™ i9-9900X	157.0	9.6%
AMD in Game mode		
AMD Ryzen™ 7 2700X	140.2	22.7%
AMD Ryzen™ Threadripper™ 2990WX	150.1	14.6%
AMD Ryzen™ Threadripper™ 2950X	150.2	14.5%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	147.9	16.3%
AMD Ryzen™ Threadripper™ 2990WX	141.1	21.9%
AMD Ryzen™ Threadripper™ 2950X	130.8	31.5%

World of Tanks

	World of Tanks (enCore benchmark score)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	38,193	
Intel® Core™ i7-8700K	36,889	3.5%
Intel® Core™ i7-8086K	36,997	3.2%
Intel® Core™ i9-9980XE	36,904	3.5%
Intel® Core™ i9-9900X	36,262	5.3%
AMD in Game mode		
AMD Ryzen™ 7 2700X	33,111	15.3%
AMD Ryzen™ Threadripper™ 2990WX	32,018	19.3%
AMD Ryzen™ Threadripper™ 2950X	32,885	16.1%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	32,535	17.4%
AMD Ryzen™ Threadripper™ 2990WX	32,282	18.3%
AMD Ryzen™ Threadripper™ 2950X	28,841	32.4%

Tom Clancy's Rainbow Six® Siege

	Tom Clancy's Rainbow Six® Siege Overall (FPS)	Performance advantage for Intel® Core™ i9-9900K	Tom Clancy's Rainbow Six® Siege Start (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	309.4		305.9	
Intel® Core™ i7-8700K	296.2	4.5%	288.2	6.1%
Intel® Core™ i7-8086K	295.6	4.7%	287.6	6.4%
Intel® Core™ i9-9980XE	301.5	2.6%	306.8	-0.3%
Intel® Core™ i9-9900X	296.9	4.2%	293.7	4.2%
AMD in Game mode				
AMD Ryzen™ 7 2700X	263.2	17.6%	258.6	18.3%
AMD Ryzen™ Threadripper™ 2990WX	271.0	14.2%	268.2	14.1%
AMD Ryzen™ Threadripper™ 2950X	277.3	11.6%	273.8	11.7%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	279.5	10.7%	275.6	11.0%
AMD Ryzen™ Threadripper™ 2990WX	256.4	20.7%	256.0	19.5%
AMD Ryzen™ Threadripper™ 2950X	282.1	9.7%	277.1	10.4%

	Tom Clancy's Rainbow Six® Siege Entrance (FPS)	Performance advantage for Intel® Core™ i9-9900K	Tom Clancy's Rainbow Six® Siege Pool room (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	252.1		269.5	
Intel® Core™ i7-8700K	242.4	4.0%	260.4	3.5%
Intel® Core™ i7-8086K	246.1	2.4%	257.6	4.6%
Intel® Core™ i9-9980XE	242.7	3.9%	256.1	5.2%
Intel® Core™ i9-9900X	242.7	3.9%	254.1	6.1%
AMD in Game mode				
AMD Ryzen™ 7 2700X	213.8	17.9%	243.1	10.9%
AMD Ryzen™ Threadripper™ 2990WX	230.3	9.5%	244.0	10.5%
AMD Ryzen™ Threadripper™ 2950X	231.2	9.0%	244.7	10.1%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	232.2	8.6%	246.1	9.5%
AMD Ryzen™ Threadripper™ 2990WX	207.7	21.4%	234.1	15.1%
AMD Ryzen™ Threadripper™ 2950X	234.0	7.7%	245.6	9.7%

	Tom Clancy's Rainbow Six® Siege Garden (FPS)	Performance advantage for Intel® Core™ i9-9900K	
Intel® Core™ i9-9900K	362.7		
Intel® Core™ i7-8700K	346.4		4.7%
Intel® Core™ i7-8086K	345.6		4.9%
Intel® Core™ i9-9980XE	357.4		1.5%
Intel® Core™ i9-9900X	350.9		3.4%
AMD in Game mode			
AMD Ryzen™ 7 2700X	299.3		21.2%
AMD Ryzen™ Threadripper™ 2990WX	307.5		18.0%
AMD Ryzen™ Threadripper™ 2950X	321.1		13.0%
AMD in Creator mode			
AMD Ryzen™ 7 2700X	324.6		11.7%
AMD Ryzen™ Threadripper™ 2990WX	294.2		23.3%
AMD Ryzen™ Threadripper™ 2950X	329.5		10.1%

PUBG - PlayerUnknown's Battlegrounds

	PUBG - PlayerUnknown's Battlegrounds (FPS)	Performance advantage for Intel® Core™ i9-9900K	
Intel® Core™ i9-9900K	214.0		
Intel® Core™ i7-8700K	213.6		0.2%
Intel® Core™ i7-8086K	209.9		2.0%
Intel® Core™ i9-9980XE	203.1		5.4%
Intel® Core™ i9-9900X	199.4		7.4%
AMD in Game mode			
AMD Ryzen™ 7 2700X	191.3		11.9%
AMD Ryzen™ Threadripper™ 2990WX	196.2		9.1%
AMD Ryzen™ Threadripper™ 2950X	198.7		7.7%
AMD in Creator mode			
AMD Ryzen™ 7 2700X	204.1		4.9%
AMD Ryzen™ Threadripper™ 2990WX	148.0		44.6%
AMD Ryzen™ Threadripper™ 2950X	179.0		19.6%

Rise of the Tomb Raider™

	Rise of the Tomb Raider™ Overall average (FPS)	Performance advantage for Intel® Core™ i9-9900K	Rise of the Tomb Raider™ Mountain Peak (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	185.8		237.5	
Intel® Core™ i7-8700K	186.1	-0.2%	241.9	-1.8%
Intel® Core™ i7-8086K	187.5	-0.9%	244.5	-2.8%
Intel® Core™ i9-9980XE	191.8	-3.1%	238.6	-0.5%
Intel® Core™ i9-9900X	183.0	1.5%	241.3	-1.5%
AMD in Game mode				
AMD Ryzen™ 7 2700X	169.1	9.9%	226.4	4.9%
AMD Ryzen™ Threadripper™ 2990WX	167.9	10.6%	233.0	2.0%
AMD Ryzen™ Threadripper™ 2950X	165.9	12.0%	231.0	2.9%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	171.9	8.1%	234.8	1.2%
AMD Ryzen™ Threadripper™ 2990WX	128.9	44.1%	189.6	25.3%
AMD Ryzen™ Threadripper™ 2950X	150.6	23.4%	206.4	15.1%

	Rise of the Tomb Raider™ Syria (FPS)	Performance advantage for Intel® Core™ i9-9900K	Rise of the Tomb Raider™ Geothermal Valley (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	160.0		155.7	
Intel® Core™ i7-8700K	163.2	-2.0%	149.4	4.2%
Intel® Core™ i7-8086K	164.1	-2.5%	150.1	3.8%
Intel® Core™ i9-9980XE	167.7	-4.6%	165.3	-5.8%
Intel® Core™ i9-9900X	153.5	4.2%	147.1	5.9%
AMD in Game mode				
AMD Ryzen™ 7 2700X	149.6	6.9%	123.9	25.6%
AMD Ryzen™ Threadripper™ 2990WX	139.1	15.0%	128.9	20.8%
AMD Ryzen™ Threadripper™ 2950X	135.9	17.7%	126.7	22.9%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	142.9	11.9%	133.3	16.8%
AMD Ryzen™ Threadripper™ 2990WX	99.0	61.6%	93.4	66.7%
AMD Ryzen™ Threadripper™ 2950X	122.6	30.4%	118.2	31.7%

Middle-earth™: Shadow of War™

	Middle-earth™: Shadow of War™ (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	155.0	
Intel® Core™ i7-8700K	155.0	0.0%
Intel® Core™ i7-8086K	155.0	0.0%
Intel® Core™ i9-9980XE	152.0	2.0%
Intel® Core™ i9-9900X	151.0	2.6%
AMD in Game mode		
AMD Ryzen™ 7 2700X	140.0	10.7%
AMD Ryzen™ Threadripper™ 2990WX	141.0	9.9%
AMD Ryzen™ Threadripper™ 2950X	143.0	8.4%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	143.0	8.4%
AMD Ryzen™ Threadripper™ 2990WX	141.0	9.9%
AMD Ryzen™ Threadripper™ 2950X	131.0	18.3%

Tom Clancy's Ghost Recon®: Wildlands

	Tom Clancy's Ghost Recon®: Wildlands (FPS)	Performance advantage for Intel® Core™ i9-9900K	Tom Clancy's Ghost Recon®: Wildlands (CPU avg %) (Lower is better)	Performance advantage for Intel® Core™ i9- 9900K
Intel® Core™ i9-9900K	131.1		19.4%	
Intel® Core™ i7-8700K	129.7	1.1%	25.7%	24.5%
Intel® Core™ i7-8086K	130.0	0.8%	25.2%	23.0%
Intel® Core™ i9-9980XE	127.5	2.9%	8.9%	-118.0%
Intel® Core™ i9-9900X	126.8	3.4%	17.1%	-13.5%
AMD in Game mode				
AMD Ryzen™ 7 2700X	121.3	8.1%	36.7%	47.1%
AMD Ryzen™ Threadripper™ 2990WX	121.8	7.6%	23.2%	16.4%
AMD Ryzen™ Threadripper™ 2950X	123.0	6.6%	21.9%	11.4%
AMD in Creator mode				
AMD Ryzen™ 7 2700X	123.7	6.0%	21.3%	8.9%
AMD Ryzen™ Threadripper™ 2990WX	Crashed in Creator mode / Ryzen Utility not installed		Crashed in Creator mode / Ryzen Utility not installed	
AMD Ryzen™ Threadripper™ 2950X	121.9	7.6%	14.4%	-34.7%

Grand Theft Auto V

	Grand Theft Auto V (FPS)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	186.5	
Intel® Core™ i7-8700K	186.0	0.3%
Intel® Core™ i7-8086K	185.4	0.6%
Intel® Core™ i9-9980XE	184.1	1.3%
Intel® Core™ i9-9900X	182.1	2.4%
AMD in Game mode		
AMD Ryzen™ 7 2700X	174.8	6.7%
AMD Ryzen™ Threadripper™ 2990WX	175.4	6.3%
AMD Ryzen™ Threadripper™ 2950X	179.6	3.9%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	175.1	6.5%
AMD Ryzen™ Threadripper™ 2990WX	161.6	15.4%
AMD Ryzen™ Threadripper™ 2950X	168.0	11.0%

Final Fantasy® XV

	Final Fantasy® XV (Benchmark score)	Performance advantage for Intel® Core™ i9-9900K
Intel® Core™ i9-9900K	10,874	
Intel® Core™ i7-8700K	10,833	0.4%
Intel® Core™ i7-8086K	10,858	0.1%
Intel® Core™ i9-9980XE	10,716	1.5%
Intel® Core™ i9-9900X	10,758	1.1%
AMD in Game mode		
AMD Ryzen™ 7 2700X	10,193	6.7%
AMD Ryzen™ Threadripper™ 2990WX	10,464	3.9%
AMD Ryzen™ Threadripper™ 2950X	10,542	3.1%
AMD in Creator mode		
AMD Ryzen™ 7 2700X	10,518	3.4%
AMD Ryzen™ Threadripper™ 2990WX	10,345	5.1%
AMD Ryzen™ Threadripper™ 2950X	10,369	4.9%

Test system information

On September 10, 2018, we finalized the hardware configurations we tested. On September 21, 2018, we installed the final Windows updates on all systems. Game updates varied, so our final software configuration changes for each game depending on when we tested it (see versions in a table below). Updates for current and recently released hardware and software appear often, so unavoidably these configurations may not represent the latest versions available when this report appears. We concluded preliminary hands-on testing on October 4, 2018. We concluded additional hands-on testing on October 12, 2018. To find details of the changes from the initial report and the October 12, 2018 updated report, see the change log on the final page of this document.

We set up 16 systems (eight different configurations with two systems each) that were mostly identical, except for the processors and motherboards. The tables below detail the configuration information for the test systems.

Test system information	Common system components used for all configurations
Memory	
Brand	Corsair® Vengeance® RGB
Amount (GB)	64 (4 x 16GB)
Type	DDR4-3000
Speed	Intel motherboards: 2,666 MHz AMD motherboards: 2,933 MHz
Graphics	
Brand	Gigabyte™ AORUS GeForce® GTX 1080 Ti 11GB (GV-N108TAORUS-11GD)
Driver	NVIDIA® 411.63
Storage	
Brand	Samsung® SSD 970 PRO
Amount	512 GB
Type	NVMe M.2
Operating system	
Vendor	Microsoft®
Name	Windows® 10 Pro
Build number or version	10.0.17134
Case	
Brand	Thermaltake Suppressor F51 E-ATX Mid-Tower
CPU cooler	
Brand	Noctua NH-U14S (Intel) Noctua NH-U14S TR4-SP3 (AMD) (Exception: The AMD Ryzen™ 7 2700X used the included AMD Wraith Prism Cooler. The other CPU units did not come with CPU coolers.)

Test system information		Common system components used for all configurations	
Power supply			
Brand	EVGA® SuperNOVA 1000 G3		
Wattage	1,000		
Display			
Brand	Dell™ Ultra HD 4K Monitor P2715Q		
Size (in.)	27		
Type	IPS-Type LCD		
Resolution	Native: 3840 x 2160 Testing: 1920 x 1080		

CPU & motherboard information

Intel processors					
Processor					
Name	Intel® Core™ i7-8086K	Intel® Core™ i7-8700K	Intel® Core™ i9-9900K	Intel® Core™ i9-9900X	Intel® Core™ i9-9980XE
Core frequency (GHz)	4.0 – 5.0	3.7 – 4.7	3.6 – 5.0	3.5 – 4.5	3.0 – 4.5
Number of cores	6	6	8	10	18
Total number of threads	12	12	16	20	36
Cache	12MB SmartCache	12MB SmartCache	16MB SmartCache	19.25MB SmartCache	24.75MB SmartCache
Motherboard					
Name	ASUS PRIME Z370-A	ASUS PRIME Z370-A	MSI Z390-A PRO	ASUS PRIME X299-DELUXE	ASUS PRIME X299-DELUXE
BIOS Version	1406	1406	E7B98IMS.108	1503	1503

AMD processors			
Processor			
Name	AMD Ryzen™ 7 2700X	AMD Ryzen™ Threadripper™ 2950X	AMD Ryzen™ Threadripper™ 2990WX
Core frequency (GHz)	3.7 – 4.3	3.5 – 4.4	3.0 – 4.2
Number of cores	8	16	32
Total number of threads	16	32	64
Cache	20MB Smart PrefetchCache	40MB Smart Prefetch Cache	80MB Smart Prefetch Cache
Motherboard			
Name	ASUS PRIME X470-PRO	ASUS PRIME X399-A	ASUS PRIME X399-A
BIOS Version	4024	0807	0807

Memory timing information

BIOS memory settings	All Intel systems	All AMD systems
Memory speed (MHz)	2,666	2,933
CAS latency (clocks)	15	15
RAS to CAS read delay (clocks)	17	17
RAS to CAS write delay (clocks)	17	17
RAS PRE time (clocks)	17	17
RAS ACT time (clocks)	35	35
Reported CAS latency (clocks)	15	16

Game versions

This table details the versions of each game we used during our tests.

Game	Version
Total War™: WARHAMMER® II	1.4.1 Build 7450.1400824
Counter-Strike®: Global Offensive	1.36.5.6
Gears of War 4	12.9.0.2
War Thunder	v.1.81.2.11
Ashes of the Singularity™	2.75.52940
Forza Motorsport 7	1.114.1881.2
Assassin's Creed®: Origins	1.51
Far Cry® 5	1.011
World of Warcraft®: Battle for Azeroth™	8.0.1 (27980) x64
Sid Meier's Civilization® VI	1.0.0.262 (362541)
Fortnite	v6.02
World of Tanks	v0.1
Tom Clancy's Rainbow Six® Siege	12298592
PlayerUnknown's Battlegrounds (PUBG)	4.8.8
Rise of the Tomb Raider™	v1.0 build 813.4_64
Middle-earth™: Shadow of War™	1.21
Tom Clancy's Ghost Recon®: Wildlands	3176580
Grand Theft Auto V	1493
Final Fantasy® XV	v1.0.0.0

How we tested

Setting up the systems

Setting up the MSI Z390-A PRO BIOS

1. Update the BIOS to E7B98IMS.108.
2. Load Optimized BIOS defaults.
3. Select Advanced mode→Settings→Advanced→Windows OS Configuration→Enable Windows 10 WHQL Support, and enable Fast Boot.
4. Select Extreme Memory Profile (X.M.P.)→Enabled.
5. Select Overclocking menu→DRAM Frequency→Set to DDR4-2666.

Setting up the ASUS PRIME X299-DELUXE BIOS

1. Update the BIOS to 1503.
2. Load Optimized BIOS defaults.
3. Select Advanced mode→AI Tweaker→AI Overclock Tuner→Set to XMP.
4. Select Advanced mode→AI Tweaker→Disable ASUS MultiCore Enhancement.
5. Select Advanced mode→AI Tweaker→DRAM Frequency→Set to DDR4-2666MHz.
6. Select Advanced mode→Boot→CSM, and set:
 - a. Boot Device Control to UEFI only.
 - b. Boot from Network Devices to Ignore.
 - c. Boot from Storage Devices to UEFI driver first.
 - d. Boot from PCI-E/PCI Expansion Devices to UEFI driver first.

Setting up the ASUS PRIME X399-A BIOS

1. Update the BIOS to 0807.
2. Load Optimized BIOS defaults.
3. Select Advanced mode→AI Tweaker→AI Overclock Tuner→Verify that D.O.C.P. is selected.
4. Select Advanced mode→AI Tweaker→Performance Enhancer→Set to Default.
5. Select Advanced mode→AI Tweaker→Disable Overclocking Enhancement.
6. Select Advanced mode→AI Tweaker→Memory Frequency→Set to DDR4-2933MHz.
7. Select Advanced mode→AI Tweaker→Set Core Performance Boost to Auto.
8. Select Advanced mode→AI Tweaker→Performance Bias→None.
9. Select Advanced mode→Boot→CSM, and set:
 - a. Boot Device Control to UEFI only.
 - b. Boot from Network Devices to Ignore.
 - c. Boot from Storage Devices to UEFI driver first.
 - d. Boot from PCI-E/PCI Expansion Devices to UEFI driver first.

Setting up the ASUS PRIME Z370-A BIOS setup

1. Update the BIOS to 1406.
2. Load Optimized BIOS defaults.
3. Select Advanced mode→AI Tweaker→AI Overclock Tuner→ Set to XMP.
4. Select Advanced mode→AI Tweaker→Disable ASUS MultiCore Enhancement.
5. Select Advanced mode→AI Tweaker→DRAM Frequency→Set to DDR4-2666MHz.
6. Select Advanced mode→AI Tweaker→Power-saving & Performance Mode→Set to Performance mode.
7. Select Advanced mode→Boot→CSM, and set:
 - a. Boot Device Control to UEFI only.
 - b. Boot from Network Devices to Ignore.
 - c. Boot from Storage Devices to UEFI driver first.
 - d. Boot from PCI-E/PCI Expansion Devices to UEFI driver first.

Setting up the ASUS PRIME X470 PRO BIOS

1. Update the BIOS to 4024.
2. Load Optimized BIOS defaults.
3. Select Advanced mode→AI Tweaker→AI Overclock Tuner→Verify that D.O.C.P. is selected.
4. Select Advanced mode→AI Tweaker→Memory Frequency→Set to DDR4-2933MHz.
5. Select Advanced mode→AI Tweaker→Performance Bias→None
6. Select Advanced mode→Boot→CSM, and set:
 - a. Boot Device Control to UEFI only.
 - b. Boot from Network Devices to Ignore.
 - c. Boot from Storage Devices to UEFI driver first.
 - d. Boot from PCI-E/PCI Expansion Devices to UEFI driver first.

Installing Windows® 10 Professional

1. Install Microsoft® Windows® 10 Professional 64-bit on each system using default options, except for no Cortana. For Privacy settings, choose No for everything.
2. In the taskbar, click the Security Center shield. Under Account Protection, click Dismiss.
3. If a dialog appears saying Fix apps that are blurry, click Cancel.
4. Install drivers:
 - a. Chipset
 - b. Video (Only install NVIDIA drivers and not and GeForce Experience utility, and select Custom and clean installation)
 - c. LAN
 - d. Intel TurboBoost® 3.0 driver (if applicable)
5. In Display settings, set the resolution to 1920 x 1080.
6. Reboot, and run Windows Updates.
7. Verify that there are no yellow bangs listed in Device Manager. If there are, fix them.
8. On AMD systems download and install the AMD Ryzen Master Utility.
 - a. Launch the utility, select Game mode for game mode testing, or select Creator mode for creator mode testing. Click Apply.

Running the tests

Complete the following tests on each of the test systems.

Final Fantasy® XV Standalone Benchmark v1.0.0.0

1. Install the Final Fantasy XV benchmark.
2. Launch the Final Fantasy XV benchmark.
3. Select High Quality, 1920 x 1080, and Fullscreen options.
4. To run the benchmark, click Start.
5. When the benchmark has finished, record the results.
6. Run the benchmark two more times, and record the results of those tests.
7. Report the median of the three test runs.

World of Tanks enCore Standalone Benchmark v0.1

1. Install the World of Tanks enCore benchmark.
2. Launch the World of Tanks enCore benchmark.
3. Select Ultra, and click Test.
4. When the benchmark has finished, record the results.
5. Run the benchmark two more times, and record the results of those tests.
6. Report the median of the three test runs.

Ashes of the Singularity™ 2.75.52940

1. Install Ashes of the Singularity.
2. Launch Ashes of the Singularity.
3. Click Play.
4. Click Options.
5. Click Video:
 - a. Select Crazy Quality Profile.
 - b. Select DirectX 12 Graphics Interface.
 - c. Uncheck VSync.
6. Click OK.
7. Click Benchmark.
8. Under Settings, select CPU Focused, and uncheck Upload Benchmark.
9. To run the benchmark, click Run Test.
10. When the benchmark has finished, record the results.
11. Run the benchmark two more times, and record the results of those tests.
12. Report the median of the three test runs.

Rise of the Tomb Raider™ v1.0 build 813.4_64

1. Install Rise of the Tomb Raider.
2. Launch Rise of the Tomb Raider.
3. Under the Display tab, on the Options screen:
 - a. Select Fullscreen.
 - b. Select Exclusive Fullscreen.
 - c. Enable DirectX 12.
 - d. Set resolution to 1920 x 1080.
 - e. Set VSync to Off.
4. Under the Graphics tab:
 - a. Select High Preset.
5. Click OK.
6. Click Play.
7. To run the benchmark, click Start Benchmark.
8. When the benchmark has finished, record the results.
9. Run the benchmark two more times, and record the results of those tests.
10. Report the median of the three test runs.

Total War™: Warhammer® 2 v1.4.1 Build 7450.1400824

1. Install Total War: Warhammer 2.
2. Launch Total War: Warhammer 2.
3. Select DirectX 12 (BETA), and click Play.
4. Click Options.
5. Click Graphics.
6. Select High Quality, 1920 x 1080 resolution, and uncheck Run in Window.
7. Click Advanced.
8. Click Benchmark.
9. Select the Battle benchmark, and click the checkmark to start the Battle benchmark.
10. When the benchmark has finished, record the results, and run the Battle benchmark two more times.
11. Select the Campaign benchmark, and click the checkmark to start the Campaign benchmark.
12. When the benchmark has finished, record the results, and run the Campaign benchmark two more times. Report the median of the three test runs.
13. Select the Skaven benchmark, and click the checkmark to start the Skaven benchmark.
14. When the benchmark has finished, record the results, and run the Skaven benchmark two more times. Report the median of the three test runs.
15. Exit the menus until you return to the main game menu.
16. Select Battles.
17. Click The Laboratory.
18. Slide the Unit size to 5x.
19. To run the Laboratory benchmark, click Benchmark.
20. When the benchmark has finished, record the results and run the Laboratory benchmark two more times. Report the median of the three test runs.

Far Cry® 5 v1.011

1. Install Far Cry 5.
2. Launch Far Cry 5.
3. Click Options.
4. Click Video.
5. Under the Monitor tab, verify that Fullscreen and 1920 x 1080 are selected.
6. Under the Quality tab, select High Graphics Quality, and click Apply.
7. Under the Advanced Settings tab, set V-Sync to Off, and click Apply.
8. To run the benchmark, click Test in Benchmark.
9. When the benchmark has finished, record the results.
10. Run the benchmark two more times, and record the results of those tests.
11. Report the median of the three test runs.

Assassin's Creed®: Origins v1.51

1. Install Assassin's Creed: Origins.
2. Launch Assassin's Creed: Origins.
3. Click Options.
4. Under the Display tab, verify that Fullscreen and 1920 x 1080 are selected, and ensure VSync is Off.
5. Under the Graphics tab, select High Graphics Quality, and click Apply.
6. Click Performance Tools.
7. To run the benchmark, click Benchmark.
8. When the benchmark has finished, record the results.
9. Run the benchmark two more times, and record the results of those tests.
10. Report the median of the three test runs.

Middle-earth™: Shadow of War™ v1.21

1. Install Middle-earth: Shadow of War.
2. Launch Middle-earth: Shadow of War.
3. Click Options.
4. Under the Display tab, verify that Fullscreen and 1920 x 1080 are selected, and that Vertical Sync is Off.
5. Under the Advanced tab, select the High Graphical Quality and click Apply.
6. Exit out of the menus until you return to the main game menu.
7. Click Run Benchmark to run the benchmark.
8. When the benchmark has finished, record the results.
9. Run the benchmark two more times, and record the results of those tests.
10. Report the median of the three test runs.

Sid Meier's Civilization® VI v1.0.0.262 (362541)

1. Install Sid Meier's Civilization VI.
2. Launch the Sid Meier's Civilization VI (DX12) -Win10 v1607+ game start option.
3. Click Game Options.
4. Click Graphics, verify that Fullscreen and 1920 x 1080 resolution are selected, and ensure that Vertical Sync is unchecked.
5. To run the AI benchmark, click Benchmark, and select AI Benchmark.
6. When the benchmark has finished, record the results, and run the AI benchmark two more times. Report the median of the three test runs.
7. To run the Graphics benchmark, click Benchmark, and select Graphics Benchmark.
8. When the benchmark has finished, record the results, and run the Graphics benchmark two more times. Report the median of the three test runs.

Gears of War 4 v12.9.0.2

1. Install Gears of War 4.
2. Launch Gears of War 4.
3. Click Enter.
4. Click Options.
5. Under the Video tab, select High Quality, and verify that Fullscreen and 1920 x 1080 are selected, Frame Rate Limit is unlimited, and that Vertical Sync is unchecked. Click Apply.
6. To run the benchmark, click Benchmark.
7. When the benchmark has finished, record the results.
8. Run the benchmark two more times, and record the results of those tests.
9. Report the median of the three test runs.

Forza Motorsport 7 (Demo) v1.114.1881.2

1. Install Forza Motorsport 7 (Demo).
2. Launch Forza Motorsport 7 (Demo).
3. Click Enter.
4. Click Options.
5. Click Video.
6. Under the Basic tab:
 - a. Dynamic Render Quality=Medium
 - b. Resolution=1920x1080
 - c. Dynamic Optimization=Custom
 - d. Fullscreen=Onscreen
 - e. Show Framerate=On
7. Click Ok, and click Yes to save changes.

8. Under the Advanced tab:
 - a. Dynamic Render Quality=Medium
 - b. Performance Target=Unlocked
 - c. Resolution Scale=100%
 - d. Anisotropic Filtering=Off
 - e. Motion Blur Quality=High
 - f. Shadow Quality=High
 - g. Particles Resolution=Full
 - h. Procedural Quality=High
 - i. Car Livery Quality= High
 - j. Mirror Quality=High
 - k. Car Model Quality=High
 - l. Particle Effects Quality=High
 - m. Wet Reflection Quality=High
 - n. MSAA Quality=Off
 - o. Lens Flare Quality=High
 - p. Windshield Reflection Quality=High
 - q. Track Texture Quality=High
 - r. Reflection Quality=High
 - s. Car Headlights in Rain=On
9. Click Ok, and click Yes to save changes.
10. Click Video.
11. To run the benchmark, click Run Benchmark.
12. When the benchmark has finished, record the results.
13. Run the benchmark two more times, and record the results of those tests.
14. Report the median of the three test runs.

War Thunder v.1.81.2.11

1. Install War Thunder.
2. Launch War Thunder.
3. Click Settings→Options.
4. Under the Graphics tab, verify that High Quality, Fullscreen, and 1920 x 1080 resolution are selected, and ensure VSync is Off.
5. Click Battles→Benchmark.
6. Select Tank Battle (CPU), and click Start to run the benchmark.
7. When the benchmark has finished, record the results.
8. Run the benchmark two more times, and record the results of those tests.
9. Report the median of the three test runs.

Tom Clancy's Ghost Recon® Wildlands v3176580

1. Install Tom Clancy's Ghost Recon Wildlands.
2. Launch Tom Clancy's Ghost Recon Wildlands.
3. Click Options.
4. Under the Video tab, verify that Fullscreen and 1920 x 1080 are selected, and ensure VSync is Off.
5. Under the Graphics tab, select the High Quality preset, and click Apply.
6. To run the benchmark, click Benchmark.
7. When the benchmark has finished, record the results.
8. Run the benchmark two more times, and record the results of those tests.
9. Report the median of the three test runs.

Tom Clancy's Rainbow Six® Siege v12298592

1. Install Tom Clancy's Rainbow Six Siege.
2. Launch Tom Clancy's Rainbow Six Siege.
3. Click Settings.
4. Click Options.
5. Under the Display tab, verify that Fullscreen and 1920 x 1080 resolution are selected, and ensure VSync is Off.
6. Under the Graphics tab, select the High Overall Quality preset, and click Apply.
7. To run the benchmark, click Benchmark.
8. When the benchmark has finished, record the results.
9. Run the benchmark two more times, and record the results of those tests.
10. Report the median of the three test runs.

Grand Theft Auto V v1493

1. Install Grand Theft Auto V.
2. Launch Grand Theft Auto V.
3. Click Settings.
4. Under the Graphics tab, select DirectX 11, Fullscreen, and 1920 x 1080 resolution, ensure that VSync is Off, and click Apply.
5. We tested with the following settings:
 - Display: 1920x1080 (FullScreen) @ 60Hz VSync OFF
 - Tessellation: 0
 - LodScale: 0.000000
 - PedLodBias: 0.000000
 - VehicleLodBias: 0.000000
 - ShadowQuality: 1
 - ReflectionQuality: 1
 - ReflectionMSAA: 0
 - SSAO: 0
 - AnisotropicFiltering: 0
 - MSAA: 0
 - MSAAFragments: 0
 - MSAAQuality: 0
 - SamplingMode: 0
 - TextureQuality: 2
 - ParticleQuality: 0
 - WaterQuality: 0
 - GrassQuality: 0
 - ShaderQuality: 0
 - Shadow_SoftShadows: 0
 - UltraShadows_Enabled: false
 - Shadow_ParticleShadows: true
 - Shadow_Distance: 1.000000
 - Shadow_LongShadows: false
 - Shadow_SplitZStart: 0.930000
 - Shadow_SplitZEnd: 0.890000
 - Shadow_aircraftExpWeight: 0.990000
 - Shadow_DisableScreenSizeCheck: false
 - Reflection_MipBlur: true
 - FXAA_Enabled: false
 - TXAA_Enabled: false
 - Lighting_FogVolumes: true
 - Shader_SSA: false
 - DX_Version: 2

- CityDensity: 0.000000
 - PedVarietyMultiplier: 1.000000
 - VehicleVarietyMultiplier: 1.000000
 - PostFX: 0
 - DoF: false
 - HdStreamingInFlight: false
 - MaxLodScale: 0.000000
 - MotionBlurStrength: 0.000000
6. To run the benchmark, click Run Benchmark Tests.
 7. When the benchmark has finished, record the results.
 8. Run the benchmark two more times, and record the results of those tests.
 9. Report the median of the three test runs.

Fortnite v6.02

1. Install Fraps version 3.5.99 Build 15627.
2. Launch Fraps.
3. Click the FPS tab:
 - a. Change the benchmarking hotkey to the space bar.
 - b. Check the boxes next to FPS, Frametimes, and MinMaxAvg.
 - c. Check the box next to Stop the benchmark after 180 seconds.
4. Install Fortnite.
5. Launch Fortnite.
6. Click Battle Royale.
7. Press the Escape key to navigate to the main menu lobby.
8. Click Menu→Settings.
9. Under the Video tab, select the High Quality preset, Fullscreen, 1920 x 1080 resolution, set the Frame Rate Limit to Unlimited, and ensure that VSync is Off. Click Apply.
10. Exit the game.
11. Copy the custom Test replay file to C:\ USERNAME\AppData\Local\FortniteGame\Saved\Demos
12. Launch Fortnite.
13. Click Battle Royale.
14. Press the Escape key to get to the main menu lobby.
15. Click Career.
16. Click Replays.
17. Select the custom Test Replay file.
18. Go to the 8:45 mark.
19. Select the correct character player.
20. Change camera to Gameplay.
21. Press H until it says Game Only HUD.
22. Press the Space Bar to start both the playback and Fraps recording.
23. When the playback has finished, go to C:\Fraps\Benchmark and view the FRAPSLOG file. Record the results.
24. Run the benchmark two more times, and record the results of those tests.
25. Report the median of the three test runs.

Counter-Strike®: Global Offensive v1.36.5.6

1. Install Counter-Strike: Global Offensive.
2. Launch Counter-Strike: Global Offensive.
3. Go to the Settings menu.
4. Go to the Game Settings tab, and set Enable Developer Console (~) to Yes.

5. In Video Settings, set the following options:
 - a. Color Mode: Computer Monitor
 - b. Aspect Ratio: Widescreen 16:9
 - c. Resolution: 1920x1080
 - d. Display Mode: Fullscreen
 - e. Laptop Power Savings: Disabled
 - f. Global Shadow Quality: High
 - g. Model/Texture Detail: High
 - h. Effect Detail: High
 - i. Shader Detail: Very High
 - j. Multicore rendering: Enabled
 - k. Multisampling Anti-Aliasing Mode: 8xMSAA
 - l. FXAA Anti-Aliasing: Enabled
 - m. Texture Filtering Mode: Anisotropic 16X
 - n. Wait for Vertical Sync: Disabled
 - o. Motion Blur: Disabled
6. Click Play CS:GO.
7. Select the Practice with Bots drop-down.
8. Select the Casual tab, and the Train map.
9. Choose Easy Bots.
10. Click Go.
11. Choose Counter-Terrorist.
12. Press the ~ key, type `record benchmarkdemo`, and press Enter.
13. Play five rounds, and then exit to the menu.
14. From the menu, press the ~ key, type `timedemo benchmarkdemo`, and press Enter.
15. Record the results from the playback.
16. Run the benchmark two more times, and record the results of those tests.
17. Report the median of the three test runs.

World of Warcraft®: Battle of Azeroth™ v8.0.1 (27980) x64

1. Install Battle.net.
2. Select World of Warcraft: Battle of Azeroth.
3. Launch World of Warcraft: Battle of Azeroth.
4. Select the character for the test, and click Enter World.
5. Press Esc, and select System.
6. Set Display Mode: Fullscreen (Windowed).
7. Set Graphics Quality to 10, and ensure that Anti-Aliasing is set to None and Vertical Sync is Disabled.
8. On the Advanced tab, uncheck Max Foreground and Max Background FPS.
9. Change the Graphics API to DirectX 12.
10. Click Okay, and restart the game to allow the graphics changes to take effect.
11. Move a Horde character to the flight master at Sanctuary of the Devoted, in Vol'Dun.
12. In the chat window, type `/timetest 1`, and press Enter. Taxi Time Test On should appear.
13. Select the flight master, and choose Isle of Fangs (in Zuldazar) as the destination.
14. Once the flight is complete, record the Average, Minimum, and Maximum FPS.
15. Repeat the procedure in the reverse travel direction.
16. Once complete, repeat steps 11 through 15 two more times. Report the median results of the three runs for each flight direction.

PUBG - PlayerUnknown's Battlegrounds v4.8.8

1. Install PlayerUnknown's Battlegrounds.
2. Launch PlayerUnknown's Battlegrounds.
3. Create a player character.
4. Select Custom Match (Open Beta).
5. Click Create.
6. Enter a server name and password.
7. Set the Map to Erangel, Perspective to TPP, and Battle Scale to Team Battle.

8. Click Create.
9. Select Match Setting.
10. Set the following rules:
 - a. Blue Circle Phase 1 values:
 - i. Wait (s): 900
 - ii. Move (s): 300
 - iii. DPS: 0.1
 - iv. Shrink: 0.99
 - b. Use Red Zone: Off.
 - c. Care Package slider: 0x.
 - d. Weather: Sunny
11. Set the following Spawns:
 - a. Throwables: 3x
 - b. Frag Grenade: 3x
 - c. Backpack: 3x
 - d. Backpack (Lv.3): 3x
12. Click Confirm.
13. Install Fraps version 3.5.99 Build 15627.
14. Launch Fraps.
15. Click the FPS tab, and:
 - a. Change the benchmarking hotkey to F11.
 - b. Check the boxes next to FPS, Frametimes, and MinMaxAvg.
 - c. Check the box next to Stop the benchmark after 180 seconds.
16. On the SUT, follow steps 1 through 4.
17. Click Settings.
18. Set Display Mode: Fullscreen.
19. Set Resolution to 1920 * 1080.
20. Set Overall Quality: High.
21. Click Apply.
22. Click Close.
23. Click Custom Match (Open Beta), and choose Normal Mode.
24. Search for the server name, and click Join.
25. Enter the password.
26. On the first machine, click Start, and then wait for the match to begin.
27. On the first machine, press F to eject the character, and set its course to land anywhere on the map.
28. On the second machine, press F to eject, and guide the player to the city Georgopol.
29. Once in Georgopol, proceed to the T-junction where the bridge road meets the block of apartments.
30. Face the buildings, and press F11 to start Fraps benchmarking.
31. Sprint to the apartment complex on the left, and enter the door.
32. Follow the left wall and collect all items in each room using the F key, opening all doors.
33. Once a level is finished, move up the stairs and follow the same procedure.
34. Around the time the player reaches the third floor and begins clearing, the timer should complete, and Fraps will record a score.
35. Use a grenade to blow up the character and end the match.
36. Go to C:\Fraps\Benchmark and view the FRAPSLOG file. Record the results.
37. Run the benchmark two more times, and record the results of those tests.
38. Report the median of the three test runs.

Version	Date published	Change(s)
1	10/8/2018	
2	10/12/2018	<p>Added game title headings to separate game results tables.</p> <p>Added new results testing AMD processors in Creator mode for all 19 games.</p> <p>Added new results for all configurations on games where the version changed.</p> <p>Adjusted number formatting (number of decimal places and comma separator) for consistency.</p> <p>Changed FRAPS to Fraps.</p> <p>Corrected a few trademarks.</p> <p>Edited our hardware/software configuration and testing dates to be more specific and reflect additional tests.</p> <p>Added Noctua NH-U14S TR4-SP3 (AMD) to the system configuration info under processor cooler, which was omitted in the original report.</p> <p>Corrected motherboard and BIOS versions we used for the AMD processors. We used the ASUS PRIME X470-PRO for AMD Ryzen™ 7 2700X, and ASUS PRIME X399-A for the AMD Ryzen™ Threadripper™ 2950X and 2990WX.</p> <p>Added a memory timings table and a table of game version numbers for easy reference.</p> <p>In step 3 of the ASUS PRIME X299-DELUXE BIOS setup steps, changed "Set to Manual" to "Set to XMP" to reflect what we did in all tests.</p> <p>In the ASUS PRIME X399-A BIOS setup steps, changed "Set to D.O.C.P. Standard" to "Verify that D.O.C.P is selected" to reflect what we did in all tests.</p> <p>In the ASUS PRIME X470 PRO BIOS setup steps, added "Select Advanced mode→AI Tweaker→AI Overclock Tuner→Verify that D.O.C.P is selected" to reflect what we did in all tests.</p> <p>In Windows 10 install steps, updated Step 8a to say "Launch the utility, select Game mode for game mode testing, or select Creator mode for creator mode testing. Click Apply."</p> <p>In the Ashes of the Singularity steps, edited from "Select High Quality Profile" to "Select Crazy Quality Profile."</p> <p>Removed an unnecessary step from Gears of War methodology, changing "Click Customization→Click Game Options" to "Click Options."</p> <p>Added a detailed list of settings we used in Grand Theft Auto V.</p> <p>Changed the times (180 seconds, 8:45 mark) in the Fortnite test steps due to the new replay video.</p> <p>Updated game versions to reflect the changes that happened when we retested.</p>

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