AMD Accelerated Parallel Processing TECHNOLOGY

# SAMPLE

# Black-Scholes Double-Precision

## 1 Overview

### 1.1 Location

`$(AMDAPPSDKSAMPLESROOT)\samples\opencl\cl\app`

### 1.2 How to Run

See the *Getting Started* guide for how to build samples. You first must compile the sample.

Use the command line to change to the directory where the executable is located. The default executables are placed in `$(AMDAPPSDKSAMPLESROOT)\samples\opencl\bin\x86` for 32-bit builds and `$(AMDAPPSDKSAMPLESROOT)\samples\opencl\bin\x86_64\` for 64-bit builds.

Type the following command(s).

1. `BlackScholesDP`
   This runs the prongram with the default option x = 4096.
2. `BlackScholesDP -h`
   This prints the help message.

### 1.3 Command Line Options

Table 1 lists, and briefly describes, the command line options.

**Table 1 Command Line Options**

| Short Form | Long Form | Description |
|---|---|---|
| -h | --help | Shows all command options and their respective meaning. |
| | --device | Devices on which the program is to be run. Acceptable values are cpu or gpu. |
| -q | --quiet | Quiet mode. Suppresses all text output. |
| -e | --verify | Verify the results against the reference implementation. |
| -t | --timing | Print timing. |
| | --dump | Dump binary image for all devices. |
| | --load | Load binary image, and execute on device. |
| | --flags | Specify compiler flags to build the kernel. |
| -p | --platformId | Select platformId to be used (0 to N-1, where N is the number of available platforms). |
| -d | --deviceId | Select deviceId to be used (0 to N-1, where N is the number of available devices). |
| -v | --version | AMD APP SDK version string. |
| -x | --samples | Number of samples to be calculated. |
| -i | --iterations | Number of iterations for kernel execution. |

## 2 Introduction

The Option pricing is a very important problem encountered in financial engineering. This sample shows an implementation of the Black-Scholes model for European Options using double-precision floating point numbers.

The most common definition of an *option* is an agreement between two parties, the *option seller* and the *option buyer*, whereby the option buyer is granted a right (but not an obligation), secured by the option seller, to carry out some operation (or *exercise* the option) at some moment in the future (see reference [1]). The predetermined price is referred to as the *strike price*, and the future date is called the *expiration date*.

The two primary option types are:

- A *call option* grants its holder the right to *buy* the *underlying asset* at a *strike price* at some moment in the future.
- A *put option* gives its holder the right to *sell* the *underlying asset* at a *strike price* at some moment in the future.

There are several factors to consider in regard to options, mostly depending on when the option can be exercised.

European options can be exercised only on the expiration date. American-style options are more flexible: they can be exercised at any time up to, and including, the expiration date; as such, they generally are priced at least as high as corresponding European options. Other types of options are path-dependent or have multiple exercise dates (Asian, Bermudian). For a call option, the profit made at the exercise date is the difference between the price of the asset on that date and the strike price, minus the option price paid. For a put option, the profit made at the exercise date is the difference between the strike price and the price of the asset on that date, minus the option price paid. Thus, the price of the asset at expiration date and the strike price strongly influence how much is paid for an option.

Other important factors in the price of an option are:

- The time to the expiration date, *T*: Longer periods imply a wider range of possible values for the underlying asset on the expiration date; this means more uncertainty about the value of the option.
- The riskless rate of return, r, which is the annual interest rate of bonds or other “risk-free” investments: Any amount of dollars, *P*, is guaranteed to be worth $P \cdot e^{rT}$ dollars *T* years from now if placed today in one of these investments; in other words, if an asset is worth *P* dollars *T* years from now, it is worth $P \cdot e^{-rT}$ today.

## 3 Black-Scholes Model

The Black-Scholes model (see reference [2]) provides a partial differential equation (PDE) for the evolution of an option price under certain assumptions. For European options, a closed-form solution exists for this PDE.

**Equation 1** $V_{call} = S \cdot PHI(d_1) - X \cdot e^{-rT} \cdot PHI(d_2)$

**Equation 2** $V_{put} = X \cdot e^{-rT} \cdot PHI(-d_2) - S \cdot PHI(-d_1)$

**Equation 3**

$$d_1 = \frac{\log\left(\frac{S}{X}\right) + \left(r + \frac{v^2}{2}\right)T}{v\sqrt{T}}$$

**Equation 4**

$$d_2 = \frac{\log\left(\frac{S}{X}\right) + \left(r - \frac{v^2}{2}\right)T}{v\sqrt{T}}$$

where

| | |
|---|---|
| $V_{call}$ | is the price for an option call. |
| $V_{put}$ | is the price for an option put. |
| $PHI(d)$ | is the cumulative normal distribution function. |
| $S$ | is the current option price. |
| $X$ | is the strike price. |
| $T$ | is the time to expiration. |
| $r$ | is the continuously compounded risk free interest rate. |
| $v$ | is the implied volatility for the underlying stock. |

The cumulative normal distribution function (see reference [3]) is computed using the Abromowitz-Stegun approximation.

# 4 Implementation Details

Each work-item calculates the sample of call and put price from a given sample of stock price, strike price, time to expiration, volatility, and sigma. If the device does not support double-precision floating point operations, the calculations are skipped. Samples are populated on the host and passed on to the device.

# 5 Recommended Input Option Settings

For best performance, enter the following on the command line: `-x 8388608 -i 10 -q -t`

# 6 References


1. http://en.wikipedia.org/wiki/Option_(finance)
2. http://en.wikipedia.org/wiki/Black-Scholes#The_model
3. Fischer Black and Myron Scholes (1973). "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy* 81 (3): 637-654.

**Contact**


**Advanced Micro Devices, Inc.**
**One AMD Place**
**P.O. Box 3453**
**Sunnyvale, CA, 94088-3453**
**Phone: +1.408.749.4000**


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