# Comparison of thermal cycler heating and cooling efficiencies

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*The Spartan DX™ has heating and cooling rates that are comparable to Peltier-controlled and fixed-temperature thermal cyclers. Using a simple temperature overshoot program, the Spartan DX can achieve significantly faster temperature transitions.*

## Introduction

A number of methods have been developed to heat and cool reaction mixtures for PCR. The GeneAmp® PCR System 9700 (Applied Biosystems) uses Peltier-based technology to ramp the temperature of a metal block. Alternatively, the RoboCycler® 96 (Stratagene) uses a robotic arm to transfer reaction tubes into full contact with fixed-temperature heat blocks. In a related way, the Spartan DX moves fixed-temperature metal blocks into partial contact with reaction tubes.

The purpose of this study was to compare the heating and cooling kinetics of the Spartan DX, RoboCycler 96, and GeneAmp 9700.

## Materials and Methods

*Determination of reaction liquid temperature*

Two thin-wire thermocouples (Omega, Part#5SRTC-TT-T-40-72) were used to measure the average reaction liquid temperature. Specifically, a thin-wall 0.2 ml polypropylene PCR tube (Axygen, Cat. No. PCR 02C) was altered in the following manner: a hole, 1 mm in diameter, was drilled into the top of the tube, two thermocouples were threaded through the hole, and the tips of the thermocouples were positioned 1-2 mm from the bottom on either side of the tube (Fig 1). 20 µl of distilled water was then added to the tube and topped with 15 µl of mineral oil to prevent evaporation. Temperature data was recorded every second for 120 s using a data logging thermometer (Fluke, 54II ). All measurements were repeated three times.

Table 1 lists the parameters for the heating and cooling programs. Note that the Spartan DX is capable of performing a temperature overshoot protocol (patent pending), where the temperature of a heating block is deliberately set higher than the desired final temperature, and the tube is moved out of contact with the block once the desired temperature is reached. For example, a block may be set at 110°C and the tube is moved out of contact with the block once a denaturing temperature of 95°C is reached.

## Results

Figure 2 and Table 2 show that the heating efficiency of the Spartan DX regular program was comparable with that of the GeneAmp 9700, while the Spartan DX overshoot program was comparable with the RoboCycler 96. With the Spartan DX regular program, it took 37 s for the reaction liquid to reach 88°C, which was comparable to 40 s with the GeneAmp 9700. In contrast, the Spartan DX overshoot program required only 20 s to reach 88°C, which was comparable to 16 s with the RoboCycler 96.

For all three machines, cooling efficiencies were more tightly distributed than for the heating efficiencies (Fig 3, Table 3). Liquid temperatures of 60°C were reached in 27 s by the Spartan DX overshoot program, 39 s by the Spartan

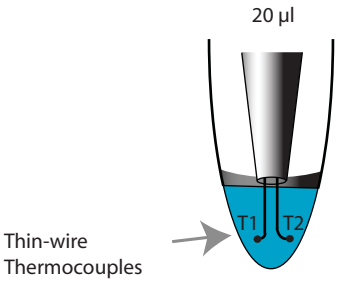


***Figure 1.*** Diagram showing positions of the thermocouples used to estimate the liquid temperature (average of T1 and T2).

| Condition | Program | Starting Temperature | Final Temperature | Time (s) |
|---|---|---|---|---|
| Heating | Regular | 60°C | 95°C | 120 |
| | Overshoot* | 60°C | 110°C | 120 |
| Cooling | Regular | 88°C | 55°C | 120 |
| | Overshoot* | 88°C | 50°C | 120 |

**Unique to Spartan DX.*

***Table 1.*** Parameters for heating and cooling programs.

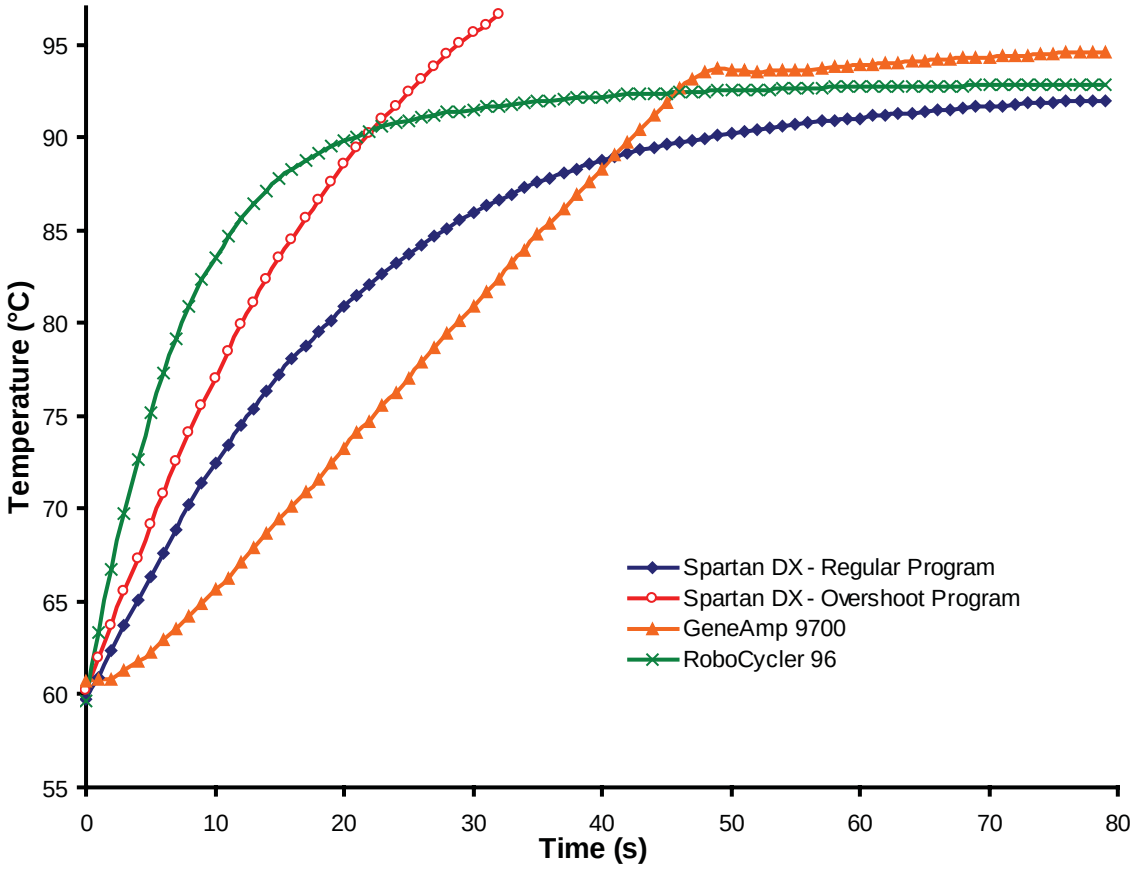


***Figure 2.*** Comparison of heating profiles. Data points are graphed as the average of three independent experiments.

| Machine | Program | Liquid Temperature | | Time to Reach 88°C | Plateau Liquid Temperature |
|---|---|---|---|---|---|
| | | 10 s | 20 s | | |
| Spartan DX | Regular | 72.5°C | 80.9°C | 37 s | 92.3°C |
| | Overshoot* | 77.1°C | 88.6°C | 20 s | N/A |
| GeneAmp 9700 | Regular | 65.6°C | 73.2°C | 40 s | 95.3°C |
| RoboCycler 96 | Regular | 83.5°C | 89.8°C | 16 s | 93.0°C |

**Unique to the Spartan DX.*

***Table 2.*** Summary of heating times and liquid temperatures. Liquid temperatures after 10 s and 20 s are shown, as well as the plateau temperatures. Note that all initial liquid temperatures were 60°C.

DX regular program, 18 s by the GeneAmp 9700, and 22 s by the RoboCycler 96.

### Discussion and Conclusions

The RoboCycler 96 achieved the fastest heating speeds, followed closely by the Spartan DX with the overshoot program. The reason is because both methods use fixed-temperature heat blocks so that less time is lost to ramping the temperature of the block. Without the overshoot program, the heating and cooling efficiencies of the Spartan DX were closer to the GeneAmp 9700. The reason is because the Spartan DX only holds the PCR tube in partial contact with the heat blocks, and therefore heats and cools slower than the RoboCycler 96 which makes full contact between the tube and the heat blocks.

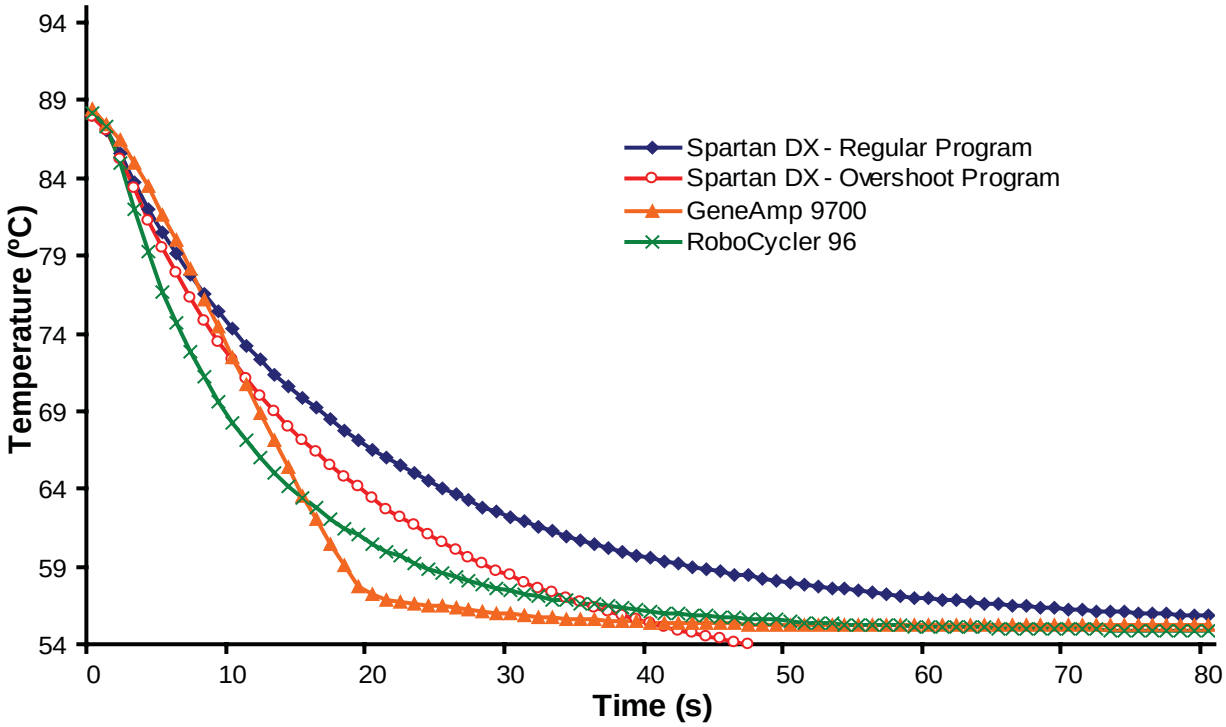


***Figure 3.*** Comparison of cooling profiles. Data points are graphed as the average of three independent experiments.

| Machine | Program | Liquid Temperature | | Time to Reach 55°C | Plateau Liquid Temperature |
|---|---|---|---|---|---|
| | | 10 s | 20 s | | |
| Spartan DX | Regular | 74.3°C | 66.5°C | 39 s | 55.2°C |
| | Overshoot* | 72.4°C | 63.4°C | 27 s | N/A |
| GeneAmp 9700 | Regular | 72.4°C | 57.2°C | 18 s | 55.3°C |
| RoboCycler 96 | Regular | 68.2°C | 60.5°C | 22 s | 54.7°C |

**Unique to the Spartan DX.*

***Table 3.*** Summary of cooling times and liquid temperatures. Liquid temperatures after 10 s and 20 s are shown, as well as the plateau temperatures. Note that all liquid temperatures started at 88°C.

Using a regular heating program, the plateau temperature reached on the Spartan DX was lower than the other two machines. The reason was because the thermocouple closest to the heat block consistently measured a higher temperature than the thermocouple positioned on the side away from the heat block. When the two readings were averaged, the maximum temperature of the Spartan DX was slightly lower than the other machines. Practically speaking, this temperature gradient across the tube does not affect successful PCR (Ref 1).

In summary, the Spartan DX achieves heating and cooling efficiencies comparable to other block thermal cyclers.

## References

1. Arbour NA, Harder CJ. (2007). Temperature overshoot improves speed of PCR. *Spartan Bioscience*. AN 006:1-3.



 