

# Randomised Benchmarking of universal qutrit gates

Explicit Randomised Benchmarking qutrit schemes are limited to Clifford gates. We introduce a **scheme to characterise a qutrit T gate**.

$$\begin{array}{c} \text{---} \boxed{X} \text{---} \\ \text{---} \boxed{T} \text{---} \\ \text{---} \boxed{D} \text{---} \end{array} \quad \begin{array}{c} \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & e^{2\pi i/9} & 0 \\ 0 & 0 & (e^{2\pi i/9})^2 \end{bmatrix} \\ \begin{bmatrix} e^{2\pi i/9} & 0 & 0 \\ 0 & e^{2\pi i/9} & 0 \\ 0 & 0 & e^{2\pi i/9} \end{bmatrix} \end{array}$$

Our scheme is a **feasible** extension to qutrits of the Dihedral Benchmarking scheme [Carignan-Dugas *et al.*]. Our scheme is the synthesis of the **Fourier method** [Merkel *et al.*] applied to non-Clifford gates.

Our scheme is important for experimental groups with qutrit implementations [Morvan *et al.*], theorists working on Randomised Benchmarking methods, and in general theorists interested in the application of Representation Theory in Quantum Information.

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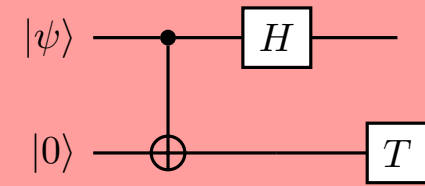


## Background

Randomised Benchmarking (RB) estimates quantum gate quality by comparing the behaviour of ideal and noisy gates, via the **average gate fidelity**  $F$  [Magesan *et al.*].



RB is used to characterize Clifford gates, T gates require an extension of the RB scheme for their characterization.



A **qutrit** is a three-level quantum system that offers advantages over qubits and is widely available in different quantum information implementations [Wang *et al.*].

## Results

RB assumes gates approximately implement transformations of a group; we introduce the HyperDihedral group to characterise a T gate. The HyperDihedral group is generated by  $X$ ,  $T$ , and  $D$ .

The name HyperDihedral is given because it is a generalisation of the Dihedral group.

Dihedral	HyperDihedral
$C_2 \times C_8$	$C_3 \times C_9 \times C_9$

We obtained the expression for the average gate fidelity for the HyperDihedral group; it has **two parameters**, accessible by using two different **initial states**. Our expression

$$F = \frac{3}{4}(1 + 2r_0 + 6r_+) + \frac{1}{4}.$$

is valid for state imperfections and gate-dependent errors.

Our method is feasible because it requires the same resources in already established RB schemes [Wang *et al.*].

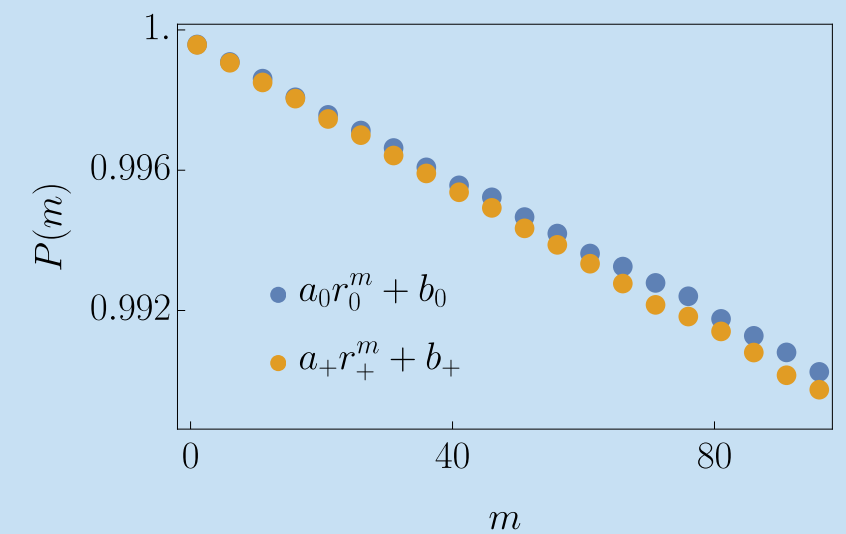


Figure 1: Survival probability  $P$  vs circuit depth  $m$  curve illustrating the relationship between the parameters that can be extracted from it to estimate the average gate fidelity shown in the second column. Density matrices  $|0\rangle\langle 0|$  and  $|+\rangle\langle +|$ , denote the initial state required to obtain parameters  $r_0$  and  $r_+$ , respectively.