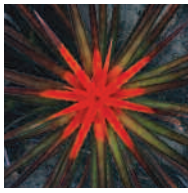
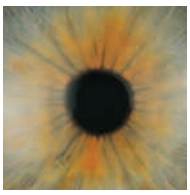
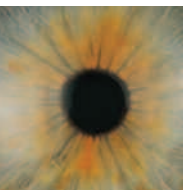
Electroporation Systems





Exceptional Systems
for Exceptional Results



Why **Electroporation?**

Because electroporation is the most popular, most versatile, most efficient transformation method available for gene expression analysis of the widest variety of cell types.

In 1928 British medical officer Frederick Griffith conducted a series of classic experiments with colonies of rough- and smooth-coated *Streptococcus pneumoniae*. These experiments led Griffith to discover the phenomenon of transformation (the assimilation of exogenous genetic material by a cell) and were an important impetus for subsequent research into the nature of the double helix by Watson and Crick. Since then, by introducing specific genetic sequences into target cells, life science researchers worldwide have exploited the phenomenon of transformation as a valuable tool for evaluating gene expression.

The most versatile and efficient transformation technique is electroporation, which uses accurately pulsed electric currents to induce transient gaps in the phospholipid bilayer of cells. Extracellular genetic material passes through these transient gaps and is assimilated by the target cells' DNA. With careful choice of appropriate pulse time, waveform, and voltage, cell membrane disturbance is minimized, target cell viability is enhanced, and reproducible transformation efficiencies of 80% are routinely achieved. For these reasons, electroporation has become the most popular transformation technique for many cell types.

The Gene Pulser Xcell™ system and the MicroPulser™ electroporator have been cited in hundreds of life science and gene expression research articles. These systems provide a patented arc-quenching design, preoptimized pulse programs for commonly studied bacteria and fungi, storage and recall of pulse parameters for the previous 100 experiments, and a user-friendly interface — and deliver reproducible results every time.

Electroporation efficiently introduces nucleic acids, siRNA duplexes, and other molecules into numerous cell types. Transiently permeabilized by a square-wave or exponentially pulsed electrical field, cell membranes readily permit exogenous molecules from the surrounding medium to enter the cell. Once inside the cell, these molecules become assimilated into the cellular DNA.

Safely and successfully used to introduce DNA, RNA, siRNAs, proteins, virions, nucleotides, carbohydrates, and even dyes into prokaryotic and eukaryotic cells, electroporation provides both an attractive alternative and a complementary adjunct to lipofection and biolistic methods of transfection.

For more information on transfection and electroporation, or to view our growing list of online protocols, visit us on the Web at **www.bio-rad.com/genetransfer/**

Choose the system you need.

The **Gene Pulser Xcell system** offers a choice of electrical field waveforms (exponential or square-wave), a choice of system configurations, and a user-friendly interface.

The Gene Pulser Xcell total system (consisting of the main unit, the CE module, the PC module, and the ShockPod™ cuvette chamber) provides full electroporation capability for both eukaryotic and prokaryotic cells.

The **MicroPulser electroporator** is a versatile, easy-to-operate instrument providing reproducible, safe transformation of bacteria, fungi, and other microorganisms.

MicroPulser —

A Simple Tool for **Transformation**

Unique Features of the System

- Faster sample handling — simple one-button pulse delivery, attached cuvette chamber, and rapid charge time
- Rapid program selection — preset programs for commonly studied bacteria and fungi
- Arc-quenching (ARQ) system that reduces arcing, protecting against loss of valuable samples
- Broad range of parameters for manual optimization; manual programming allows voltage to be selected in a 200–3,000 V range with 10 V precision, and pulse width to be adjusted in a 1.0–4.0 ms range with 0.1 ms precision
- 3,000 V capability for improved efficiency in cuvettes with larger volume
- Compact, space-saving design
- Audible and visible pulse indicators
- Display of time constant and actual voltage delivered, to monitor reproducibility

The MicroPulser is a robust, state-of-the-art electroporator that provides safe, efficient, and reproducible transformation of bacteria, fungi, and other microorganisms. Transformation efficiencies much higher than those obtained by chemical methods can be achieved by electroporation. Pulses are easily delivered by choosing a preset program and pushing a button.

Why Electroporation With the MicroPulser?

Efficient

Electroporation is the most efficient bacterial transformation method available. It is orders of magnitude more efficient than chemical methods, and provides results that are more reproducible. The MicroPulser is designed to deliver consistent electrical conditions for electroporation of *E. coli*, fungi, and other microorganisms, resulting in the highest efficiencies possible. The preset programs are tested for commonly studied bacteria and fungi. Voltage and pulse time can be set manually, enabling you to optimize transformation conditions for your experiment.

Compact and User-Friendly

The all-in-one design and preset conditions precisely deliver the optimal parameters for bacteria and fungi, established by Bio-Rad and verified in the literature over the years. This allows efficient transformation with minimum effort and time. The small footprint saves valuable bench space.

Flexible

You can choose voltages between 200 and 3,000 V, to transform the widest range of microorganisms. By using a larger-capacity cuvette and increasing voltage to maintain the same field strength, you can process large samples and increase your throughput.

Programmed Functions

Program	Species	Cuvette Size (cm)	Preset Conditions*
Bacteria			
Ec1	*Escherichia coli*	0.1	1.80 kV, 1 pulse
Ec2	*Escherichia coli*	0.2	2.50 kV, 1 pulse
StA	*Staphylococcus aureus*	0.2	1.80 kV, 1 pulse, 2.5 ms
Agr	*Agrobacterium tumefaciens*	0.1	2.20 kV, 1 pulse
Ec3	*Escherichia coli*	0.2	3.00 kV, 1 pulse
Fungi			
Sc2	*Saccharomyces cerevisiae*	0.2	1.50 kV, 1 pulse
Sc4	*Saccharomyces cerevisiae*	0.2	3.00 kV, 1 pulse
ShS	*Schizosaccharomyces pombe*	0.2	2.00 kV, 1 pulse
Dic	*Dictyostelium discoideum*	0.4	1.00 kV, 2 pulses, 1.0 ms
Pic	*Pichia pastoris*	0.2	2.00 kV, 1 pulse

* Unless the pulse time is truncated below 5 ms, the unit will deliver the optimal time constant of ~5 ms to samples in high-resistance media.

Gene Pulser Xcell —

An Exceptional System for **Excellent Results**

Unique Features of the System

- Provides both exponential and square waveforms
- Supports electroporation of all cell types, prokaryotic and eukaryotic
- Uses Bio-Rad's patented* PulseTrac™ circuitry to ensure reproducible results
- Offers value and flexibility for changing research needs because of modular design
- Delivers up to 3,000 V
- Includes the unique ShockPod shocking chamber for one-handed operation

Programming Capabilities

- User-friendly digital interface for easy, intuitive programming and display of all experimental parameters
- Preset programs for frequently used microbial and mammalian cell lines
- Manual programming, which enables entry or editing of all parameters for exponential or square-wave delivery, or assisted programming using the time constant required
- Optimization protocol that enables the best conditions to be determined using incremental voltage steps
- Delivery parameters given for time constant, actual sample voltage, pulse interval, and pulse time, depending on the waveform chosen
- User method storage for 144 programs
- Storage and recall of pulse parameters and results for previous 100 experiments

* US patents 4,750,100 and 4,910,140.

The Gene Pulser Xcell is a flexible, modular pulse delivery system that uses exponential or square-wave pulses to deliver the pulses optimal for your cell type.

Innovative Modular Design for Every Cell Type

The modular Gene Pulser Xcell system is built upon the main unit. The CE module contains the low-voltage capacitors required for mammalian cells and plant protoplasts. The PC module contains the resistors needed for high-voltage electroporation. The system is available in three combinations.

Gene Pulser Xcell Total System

The total system includes both the PC module and the CE module and provides full capability to electroporate both eukaryotic and prokaryotic cells using either exponential or square-wave pulses.

Gene Pulser Xcell Eukaryotic System

Consisting of the main unit and the CE module, the eukaryotic system enables electroporation of mammalian cells and plant protoplasts. With a range of 25–3,275 µF, the CE module provides a means of controlling the capacitance of the circuit by increasing the time constant of the pulse. For square-wave pulses, the CE module provides the large capacitor necessary for delivering a square-wave pulse into low-resistance media.

Gene Pulser Xcell Microbial System

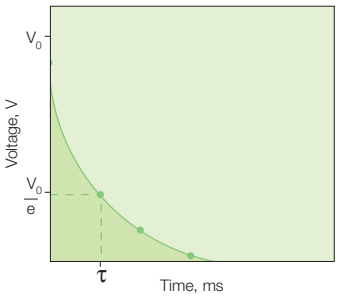
Consisting of the main unit and the PC module, the microbial system enables electroporation of bacteria and fungi, as well as other applications where high-voltage pulses are applied to samples of small volume and high resistance. By placing resistors in parallel with the sample, the PC module controls the resistance of the circuit, providing a means of reducing the time constant of an exponential-decay pulse.

Exponential and Square-Wave Pulses

The Gene Pulser Xcell system generates both exponential and square waveforms, enabling you to choose the waveform and protocol that will work best for your cells.

Exponential Decay

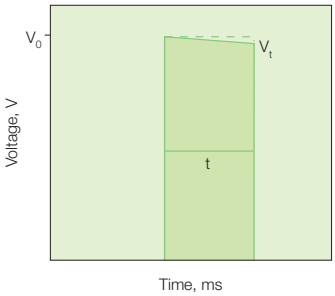
The chosen voltage is released from the capacitors and decays exponentially over time. The delivered pulse is characterized by two parameters, the field strength (E, expressed in kV/cm) and the time constant (t). The field strength is controlled by adjusting the voltage on the Gene Pulser Xcell system for a known electrode distance. Resistance and capacitance can also be selected using the interface. Following the pulse, the instrument will display values for the actual volts delivered and the time constant.



Exponential-decay pulse. When a capacitor charged to a voltage V_0 is discharged into cells, the voltage applied to the cells decreases over time exponentially. The time required for the initial voltage to drop to V_0/e (where e is the base of the natural logarithm) is referred to as the time constant, τ, a convenient expression of the pulse length.

Square Wave

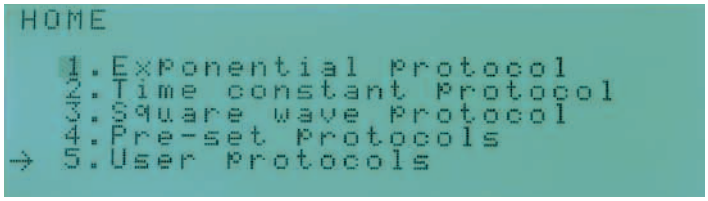
For some cell lines, particularly sensitive lines that are easily damaged using exponential-decay waves, square waves offer increased efficiency and viability. Square-wave pulses are characterized by the voltage delivered, the length of each pulse, the number of pulses, and the length of the interval between pulses. All of these parameters can easily be set using the Gene Pulser Xcell interface. Following the pulse, the instrument will display the actual volts delivered, the pulse time, and the interval time, when multiple pulses are used.



Square-wave pulse. Truncating the pulse from a capacitor after discharging it into the sample generates a square-wave pulse. The pulse length is the time the cells are subjected to the discharge. A slight drop in voltage occurs with all square-wave instruments. This drop in voltage is called the pulse droop and is measured as a percentage of the initial voltage.

User-Friendly Interface

The graphical interface on the main unit controls all functions, including those of any connected accessory modules. The interface consists of a single screen with function keys and an alphanumeric keypad. Programming is simple and intuitive using onscreen prompts. The screen is used for programming, and to display stored and preset protocols, parameters delivered, and a graphic of the pulse waveform.



All programs are easily accessed from the Home screen.

Reliable and Safe Performance With PulseTrac Circuitry

Microprocessor-controlled circuitry ensures that only the highest-quality electroporation pulses are consistently delivered while offering maximum sample protection. The PulseTrac system monitors and adjusts for the total resistance and capacitance of the complete circuit, including the sample in the cuvette, to provide accurate delivery.

PulseTrac Features

- Facilitates capacitor recalibration to maintain accurate pulse specification over time
- Provides prepulse sample resistance measurement
- Reduces the risk of arcing in the high-voltage circuit, protecting both instrument and sample
- Tightens the already rigorous precision of the low-voltage capacitors in the CE module from 10% to 20%
- Enables safe, automatic discharge of current if the pulse or circuit is interrupted

Optimization Protocol

Optimal delivery conditions need to be determined for each new experimental system by using a series of preliminary experiments to determine the ideal pulse parameters. The optimization protocol will enable you to determine the best conditions using incremental voltage steps.

Preset Programs for Commonly Used Microbial and Mammalian Cells

The Gene Pulser Xcell system presents specific pretested parameters for the most frequently used cell lines.

Available Preset Programs for Selected Cell Lines*

Mammalian	Bacterial	Fungal
A549	*Escherichia coli*	*Saccharomyces cerevisiae*
BHK21	*Agrobacterium tumefaciens*	*Pichia pastoris*
CHO	*Pseudomonas aeruginosa*	*Candida albicans*
COS-7	*Staphylococcus aureus*	*Schizosaccharomyces pombe*
CV1	*Bacillus cereus*	*Dictyostelium discoideum*
HEK 293	*Streptococcus pyogenes*	
HeLa	*Lactobacillus plantarum*	
HL60		
HuT78		
Jurkat		
K562		
NIH 3T3		

* Detailed parameters can be found for each of these cell lines, with details for the preparation of electro-competent cells, in the Gene Pulser Xcell instruction manual or at **www.bio-rad.com/genetransfer/**

User Method Storage

Every researcher has preferred methods for electroporating specific cell types. The method storage program enables 12 users to each store 12 programs. The programs can be saved by name using the alphanumeric keypad.

Electro-Competent Cells

Bio-Rad's EP-Max™10B and EP-Max10B F' cells are perfect for the most demanding applications, where consistent, high-efficiency transformations are critical to experimental success. EP-Max10B T1-resistant cells maintain the *tonA* marker, for added protection from T1 and T5 phage infections.

Bio-Rad's high-quality electro-competent cells are also available in a convenient EasyShock™ format. EP-Max10B cells are provided frozen, in 1.0 cm gap electroporation cuvettes, for high transformation efficiencies in a simple four-step protocol.

EP-Max Cell Features

- Blue/white screening
- Transformation efficiencies >1 x 10^{10} cfu/µg DNA
- Accepts methylated DNA
- *recA* and *endA* mutations for high-quality plasmids
- Transformable by plasmids as large as 50 kb
- Produced with manufacturing controls to ensure consistent performance

Cuvettes

Bio-Rad's high-quality electroporation cuvettes provide consistent pulse delivery to your valuable samples, ensuring reproducible results. Cuvettes are available in three different gap widths (0.4, 0.2, and 0.1 cm) for optimal field strength delivery to a wide range of cell types.

Bio-Rad Cuvette Features

- High-quality construction for consistent performance
- Gamma-irradiated to ensure sterility
- Color-coded caps for easy identification
- Available in several package sizes

Electroporation Cuvette Selection Guide	
0.4 cm gap cuvettes	Wider gap for low field strength, used for mammalian and other eukaryotic cells
0.2 cm gap cuvettes	Narrow gap for high field strength, used for yeast, bacterial, and eukaryotic cells
0.1 cm gap cuvettes	Narrowest gap and shallow bottom for small sample volumes (40–80 µl) and very high field strength, used for yeast and bacterial transformation

Ordering Information

Catalog #	Description
Cuvettes	
Standard Packs	
165-2088	Gene Pulser/MicroPulser Cuvettes, 0.4 cm gap, 50 (regular pack)
165-2086	Gene Pulser/MicroPulser Cuvettes, 0.2 cm gap, 50 (regular pack)
165-2089	Gene Pulser/MicroPulser Cuvettes, 0.1 cm gap, 50 (regular pack)
Jumbo Packs*	
165-2091	Gene Pulser/MicroPulser Cuvettes, 0.4 cm gap, 500 (jumbo pack)
165-2092	Gene Pulser/MicroPulser Cuvettes, 0.2 cm gap, 500 (jumbo pack)
165-2093	Gene Pulser/MicroPulser Cuvettes, 0.1 cm gap, 500 (jumbo pack)
Mini Packs	
165-2081	Gene Pulser/MicroPulser Cuvettes, 0.4 cm gap, 5 (mini pack)
165-2082	Gene Pulser/MicroPulser Cuvettes, 0.2 cm gap, 5 (mini pack)
165-2083	Gene Pulser/MicroPulser Cuvettes, 0.1 cm gap, 5 (mini pack)

* Please inquire about volume pricing.

Gene Pulser Xcell System Specifications

Gene Pulser Xcell Total System
For prokaryotic and eukaryotic cells; includes main unit, CE module, PC module, ShockPod

Outputs	Waveform: Exponential-decay or square-wave Voltage: 10–3,000 V
Capacitance	10–500 V: 25–3,275 µF in 25 µF increments 500–3,000 V: 10, 25, 50 µF
Resistance (parallel)	50–1,000 Ω in 50 Ω increments, plus infinity
Sample resistance	20 Ω minimum at 10–2,500 V 600 Ω minimum at 2,500–3,000 V
Square-wave timing	10–500 V: 0.05–10 ms duration in 0.05 ms increments, 10–100 ms duration in 1 ms increments, 1–10 pulses, 0.1–10 sec interval 500–3,000 V: 0.05–5 ms duration in 0.05 ms increments, 1–2 pulses, 5 sec minimum interval

Gene Pulser Xcell Eukaryotic System
For mammalian cells and plant protoplasts; includes main unit, CE module, ShockPod

Outputs and other specifications	Same as total system without the parallel resistance

Gene Pulser Xcell Microbial System
For bacteria and fungi; includes main unit, PC module, ShockPod

Outputs	Waveform: Exponential-decay or square-wave Voltage: 200–3,000 V
Capacitance	10, 25, 50 µF
Resistance (parallel)	50–1,000 Ω in 50 Ω increments, plus infinity
Sample resistance	20 Ω minimum at 200–2,500 V 600 Ω minimum at 2,500–3,000 V
Square-wave timing	0.05–5 ms duration in 0.05 ms increments, 1–2 pulses, 5 sec minimum interval

Gene Pulser Xcell Main Unit

Outputs	Waveform: Exponential-decay or square-wave Voltage: 200–3,000 V
Discharge capacitance	10, 25, 50 µF
Sample resistance	20 Ω minimum at 200–2,500 V 600 Ω minimum at 2,500–3,000 V
Square-wave timing	0.05–5 ms duration in 0.05 ms increments, 1–2 pulses, 5 sec minimum interval

General

Input voltage	100–120 VAC or 220–240 VAC, 50/60 Hz
Power	Maximum 240 W (during short charging periods)
Operating environment	Temperature 0–35°C, humidity 0–95% (noncondensing)
Regulatory	Safety EN 61010, EMC EN61326 Class A
Dimensions (W x D x H)	Main unit: 31 x 30 x 14 cm CE module: 31 x 28 x 9 cm PC module: 31 x 28 x 5 cm
Weight	Main unit: 6.6 kg CE module: 3.1 kg PC module: 1.9 kg

MicroPulser Electroporator Specifications

Input voltage	Automatic mains voltage switching, 100–120 V or 220–240 V
Input current	2 A RMS (100–120 V) 1 A RMS (220–240 V)
Maximum output voltage and current	3,000 V peak into >600 W load; limited at 100 A peak maximum
Output waveform	Decaying or truncated-decaying exponential waveform with RC time constant of 5.0 ms assuming loads of 3.3 kΩ
Output voltage and pulse duration adjustment	Voltage adjustable in 200–3,000 V range with 10 V precision; 5 ms default or 1–4 ms with 0.1 ms precision; 5 bacterial and 5 fungal preset programs
Operating environment	Temperature 3.5–35°C, humidity 0–95% (noncondensing)
Dimensions (W x D x H)	29 x 21 x 8 cm
Weight	2.9 kg

Ordering Information

Catalog #	Description
MicroPulser Electroporator	
165-2100	MicroPulser Electroporator, includes a cuvette chamber with leads, 10 sterile cuvettes (5 each of 0.1 cm and 0.2 cm gap)
Gene Pulser Xcell Systems and Components	
165-2660	Gene Pulser Xcell Total System, for mammalian and microbial cells, 100/240 V, 50/60 Hz, exponential and square-wave delivery, includes main unit, CE module, PC module, ShockPod chamber, 15 sterile cuvettes (5 each of 0.1, 0.2, and 0.4 cm gap), instructions
165-2661	Gene Pulser Xcell Eukaryotic System, 100/240 V, 50/60 Hz, exponential (25–3,275 µF range) and square-wave delivery, includes main unit, CE module, ShockPod chamber, 5 sterile cuvettes (0.4 cm gap), cuvette rack, instructions
165-2662	Gene Pulser Xcell Microbial System, 100/240 V, 50/60 Hz, exponential-decay delivery, includes main unit, PC module, ShockPod chamber, 10 sterile cuvettes (5 each of 0.1 and 0.2 cm gap), cuvette rack, instructions
165-2666	Gene Pulser Xcell Main Unit, 100/240 V, 50/60 Hz
165-2667	Gene Pulser Xcell CE Module, 25–3,275 µF range controlled by main unit, includes integral leads
165-2668	Gene Pulser Xcell PC Module, 50–1,000 Ω range controlled by main unit, includes integral leads
165-2669	Gene Pulser Xcell ShockPod Cuvette Chamber, includes integral leads for connection to Gene Pulser Xcell, Gene Pulser® II, or MicroPulser electroporators