

# MUSICAL POLYBIUS CIPHER

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## 1. POLYBIUS CIPHER

The *Polybius* cipher square is a 5 by 5 array used in Ancient Greece to send secret messages. Encryption of a letter is done by assigning a pair of numbers, one from the left most column followed by a second from the top row [1]. To further enhance encryption, Kondo and Mselle [1] expanded the original Polybius into an 8 by 8 array.

	1	2	3	4	5
1	A	B	Γ	Δ	E
2	Z	H	Θ	I	K
3	Λ	M	N	Ξ	O
4	Π	P	Σ	T	Υ
5	Φ	X	Ψ	Ω	

Ancient Greek Polybius

	1	2	3	4	5	6	7	8
1	P	O	L	Y	2	0	1	3
2	A	B	C	D	E	F	G	H
3	I	J	K	M	N	Q	R	S
4	T	U	V	W	X	Z	4	5
5	6	7	8	9	!	"	#	
6	\$	%	&	'	(	)	*	+
7	,	-	.	/	:	;	/	=
8	>	?	@	[	\	]	^	_

Extended Polybius Cipher [1]

## 2. EXTENDED MUSICAL POLYBIUS CIPHER

In a musically extended Polybius square, musical notes from the C Major scale are used in place of numbers. A character is encrypted by two notes. The first note is assigned to the treble clef of a music sheet, while the second note to the bass clef. Thus, a message encoded on a music sheet that can be read and performed. Encryption can be further enhanced by including sharps and flats to increase difficulty in deciphering and help brighten up the sound.

	C	D	E	F	G	A	B	ξ
C	A	X	/	1	M	)	P	H
D	2	B	=	I	C	@	+	5
E	Q		C	]	J	3	~	]
F	4	R	9	0	?	K	\$	D
G	V	&	÷	!	E	6	L	O
A	,	W	-	T	'		_	7
B	Y	%	X	"	U	#	G	>
ξ	S	Z	<	8	[	F	N	*

Extended Polybius Cipher with Musical Notes

Plaintext Position	H	E	L	0		W	O	R	L	D	!
Ciphertext	C	G	G	B	G	D	A	ξ	F	B	F
Ciphertext	ξ	G	B	G	ξ	E	D	G	D	G	F

Encryption for Extended Musical Polybius



Original Musical Cipher for HELLO WORLD!

## 5. FURTHER RESEARCH

Continue developing the 12 by 12 Polybius Cipher.

Permutations of 144 for placement of letters, numbers, and symbols.

Convert all permutations into a CVS file.

What other items could be placed in the blank spaces squares?

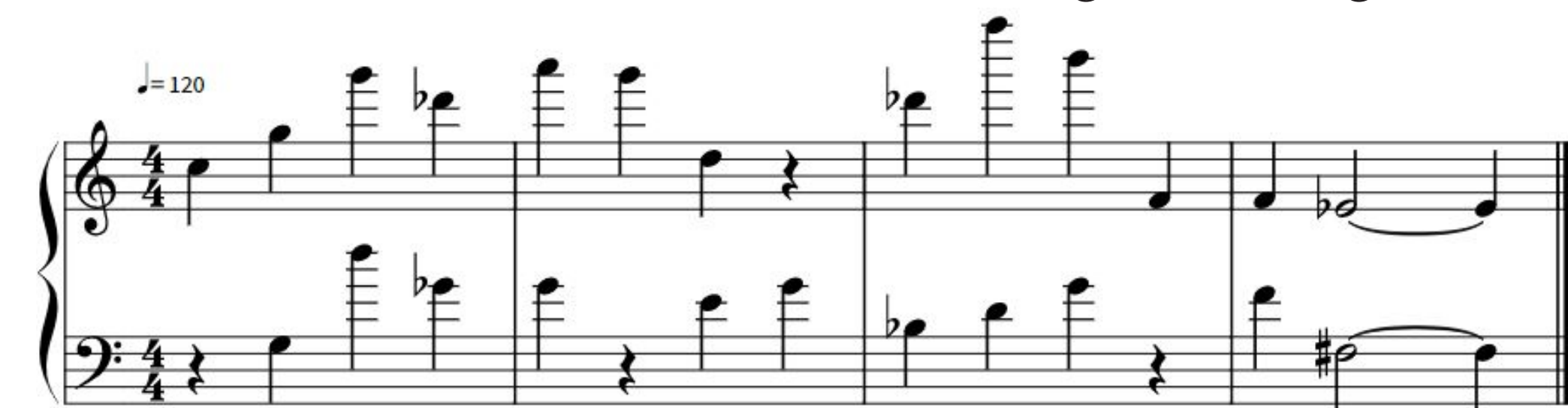
## 3. DEGREE AND BEAT SUBSTITUTION

In music theory, note sound frequency is grouped by numbers with the lowest sound 0 to the highest, 9. Changing the frequency degree can further strengthen encryption. Treble clef notes are substituted by degrees of 4, 5, 6, and bass-clef notes are substituted by 2, 3, and 4. Symbols, numbers, and spaces are substituted by 4 in the treble-clef staff and 3 in the bass-clef which are rewritten into the original encryption for the receiver.

4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3

Plaintext Position	H	E	L	L	0		W	O	R	L	D	!
Ciphertext	C <sub>5</sub>	G <sub>5</sub>	G <sub>6</sub>	B <sub>6</sub>	G <sub>6</sub>	D <sub>4</sub>	A <sub>5</sub>	ξ	F <sub>6</sub>	B <sub>6</sub>	F <sub>4</sub>	F <sub>4</sub>
Ciphertext	ξ	G <sub>3</sub>	B <sub>4</sub>	G <sub>4</sub>	ξ	E <sub>4</sub>	D <sub>3</sub>	G <sub>4</sub>	D <sub>4</sub>	G <sub>4</sub>	ξ	F <sub>4</sub>

HELLO WORLD! with Scale Degree Change



Original Cipher for HELLO WORLD! with Degree Change Sharps/Flats.

Each measure with a 4||4 count constitutes four beats per measure. Thus, a quarter note represents one beat, and the other notes have beats as indicated in the following table.

Note	Whole	Half	Quarter	Eight	Triplet	Sixteenth
Beats	4	2	1	1/2	13	1/4

Letter	A	B	C	...	X	Y	Z	Space	Symbols	Numbers
Note	4	2	1	...	1/4	4	2	1	1/2	1/3

Beat Substitution of Alphabet, Spaces, Symbols, and numbers.



Musical Cipher for HELLO WORLD! with Beat Substitution

## 6. REFERENCES

- [1] Tabu S. Kondo and Leonard J. Mselle. An Extended Version of the Polybius Cipher. *International Journal of Computer Applications*, 79(13):30–33, October 2013.
- [2] M. Yamuna and Siddarth and Harish V. Sankar, A. and Ravichandran. Encryption of a Binary String Using Music Notes and Graph theory. *International Journal of Engineering and Technology*, 5:2920–2925, 06 2013.
- [3] Norissa Lamaute, Alexa Piccoli, Li-Chiou Chen, and Andreea Cotoranu. A Substitution Cipher for Musical Cryptography. In *Proceedings of Student-Faculty Research Day, CSIS, Pace University*.

## 4. 12 BY 12 MUSICAL POLYBIUS CIPHER

Converting the 8 by 8 Polybius into a musical cipher increases complexity in encryption. Thus, extending the Musical Polybius into a 12 by 12 array would further strengthen it. This uses all original C Major music notes in addition to flat notes. Encryption follows as the old way, the first letter is assigned by a note from the left-most column and the second from the top row, switching when assigning the second letter. The pair of notes are then placed in the treble-clef and bass-clef staves respectively.

	C	D	D♯	E	E♭	F	G	G♯	A	A♭	B	B♭
C	]		+		{		>		,		=	+
D					4				.			-
D♯	"	B	C		?	1			V	W		
E	A			D			I		U	÷		X
E♭	Z	]			E		T					3
F	(		9		¿	F	S		5	/		)
G	8			\$		R	G		i	@		!
G♯	Y	-			Q			H				0
A	M		.	P	&			I				L
A♭		N	O				π		J	K		
B	#				*	2						:
B♭		>		7			<	6			\$	\

12 by 12 Polybius Cipher

Plaintext Position	H	E	L	L	O		W	O	R	L	D	!
Ciphertext	G♯	E♭	A	B♭	A♭	F	D♭	D♭	G♯	B♭	E	B♭
Ciphertext	G♯	E♭	B♭	A	D♭	C	B	A♭	F	A	E	G♭



Musical Cipher for HELLO WORLD! Using 12 by 12 Polybius Square

The use of permutations could be a way to fill out the 12 by 12 array. A Python program code is being developed to generate all the permutations of the entries of an array and reshape it into a square matrix. Currently, we are trying to write all the permutations into a CSV file to reduce computing load.

