# Microtonal Notation: LilyPond as a score editor for Bohlen-Pierce Scales

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*Abstract*— **Composers working with microtonal systems face a unique challenge: the difficult task of notating non-twelve-tone pitches on a standard staff system. A consideration of the scores of Carillo, Haba and Blackwood demonstrate that a turnkey notation solution for all microtonal scales may never be found, but customised individual systems can be of great benefit to the composer and to the performer. The preservation of clarity is paramount, so that the intent of the composer can be easily conveyed to the performer through the medium of the adapted score system. Conversely, a good system will facilitate the transmission of notated communications from the performer back to the composer for the purposes of editing and revision.**

**This paper sets out to trace the evolution of the score for a microtonal work, which makes use of the Bohlen-Pierce (B-P) scale, and which uses the LilyPond notation editor to engrave the score. The pitch span of the B-P scale is defined on conventional staves, and these have been reassigned to the B-P pitch values. New customised clefs have been traced by coding bespoke PostScript graphical objects into the LilyPond files, and these microtonal clef glyphs override the traditional bass, treble and alto clefs. With this system, it is intended that performers, after some initial training, will feel sure of the pitch assignments for the new staves, as they resemble conventional staves. In addition to the scoring system, this paper introduces: a performance-ready timbral selection method created in Pure data; a pair of bespoke B-P keyboard manuals with performance control features.**

**Keywords: microtonality, Pure data, interfaces, Bohlen-Pierce, DIY, repurposed.**

### *Introduction*

Attempting to use standard music notation to notate microtonal scores can create a number of issues for the musician new to the world of microtonality. There is the question of tonal context, and the pragmatic occurrence that music which consists of even divisions of the twelve-tone equal-tempered system (quarter-tones, eight tones etc.) is often used for effect rather than as a viable operator in a harmonic system, or as a foil to a tonal backdrop as in the music of Carrillo. There are trends of development, with a plethora of notational systems launched in the twentieth century as composers invented a new notation for each new composition. Just Intonation (JI) notation systems are useful for those familiar with JI as they assume a knowledge of common JI intervals, e.g., the interval of a syntonic comma (81/80) is used as an 'pitch adjuster', added to and subtracted from pitch values in the Helmholtz-Ellis JI pitch notation system. This is specific to JI, and not so useful outside of this subset of the microtonal continuum.

Some of the issues surrounding this are highlighted in Skinner's thesis: he compares notation systems by Blackwood, Carillo and Haba, and this is a telling summary in that it shows how many different systems can exist once one travels beyond the boundaries of the 12-TET system [1]. Likewise, Karkoschka's commentary on contemporary notation presents a bewildering array of score formats, some of these perhaps more at home in the gallery than in the performance venue [2]. What many of these scores do have in common is that they are, in many instances, modifications of traditional notation. The practice in that era was to create an entirely new bespoke notation system for each microtonal scale, and inevitably clarity was compromised. When performing a new piece written in a bespoke system, the microtonal performer is faced with a new set of notational conventions, and confusion is only allayed by a substantial familiarisation process in which the idiosyncrasies of the system in question are teased out.

These were some of the issues that were a cause for concern when the initial groundwork was laid for the creation of a customised solution for notating the Bohlen-Pierce scale. It is part of the nature of the project that it is authored in open-source software,

and that it enlists musicians of intermediate skill level. For this reason, the score needed to be clear and unambiguous, and free from an overuse of cryptic symbols. The project also proposes customised keyboard controller interfaces for the purpose of controlling the B-P sound creation engine, and a notation system congruent with these novel manuals is desirable.

## I. The Bohlen-Pierce Scale

### A. Description

The Bohlen-Pierce scale was independently developed (or discovered) by Heinz Bohlen, Kees van Prooijen, and John R. Pierce; they published their findings over the period 1978-1984. The scale describes the division of the twelfth (an octave and a fifth), or *tritave* in B-P nomenclature, into thirteen divisions. These divisions can be equal-tempered or just-intonation scale steps. The rationale for the scale was based on the triadic identity 3:5:7, and this corresponds to the familiar 4:5:6 triad upon which the twelve-tone Equal Tempered (12-TET) system is based. The *tritave* span means that the scale is a non-octave scale: the 'point of repeat' occurs at the twelfth, which is next most consonant interval after the octave. This is defined as a *pseudo-octave*: a sense of arrival is perceived by the listener; and the *tritave* interval exhibits a high level of consonance[1]. The scale exists in a number of versions: there is a chromatic B-P scale; there is a mode which consists of nine diatonic steps (Bohlen); and a mode of seven diatonic steps (van Prooijen) [3] [4] [5].

## II. Creating the System

### A. Bohlen's System

Bohlen's original paper proposes a system of B-P keys with attendant key signatures – although it is a bespoke system and designed for the scale, it suffers from similar issues as other microtonal scoring systems in that it is unwieldy and confusing to the average musician [3]. At this point in the project a survey was undertaken to try and find a more accessible solution. The innovative performing group TranSpectra have fostered a repertoire based on the B-P scale: they perform on custom-designed B-P clarinets[2], and have proposed an accidental-free notation system that uses a system with three staves to represent the entire span of B-P pitches.[4] Since the basic B-P interval is wider than the (corresponding) half-step in 12-EDO, the system successfully represents the entire range without the engraver having to resort to the excessive use of ledger lines.

### B. 'Shape Note' modification

It became apparent during one workshop that the dearth of accidentals in the new scoring system actually created confusion as it was difficult for the performer to discriminate between pitches. The solution to this problem came from an unlikely source: a conversation with a colleague on the subject of Sacred Harp singing led to the notation system used by nineteenth century community singers known as Shape Note.

Shape Note notation is, in essence, a simplification of the Guidonian system, the harmonic functions are assigned different note head shapes, and commonly related functions are ascribed the same shape, e.g., (diatonic major) scale step ii and scale step v (supertonic and dominant respectively) are assigned the same note head graphic. Since the score needed to be easily readable, and the performers had to be able to ascertain the pitch reference quickly, the use of adapted note heads gives the performer an immediately recognisable visual cue, and this leads the ear directly to the correct pitch. In addition, the assignment of note head shapes to related B-P harmonic functions provides a powerful aid to learning the harmonic tendencies of the scale, and this can be of great assistance when improvising.

[1] When played with harmonic timbres, especially those with spectra containing odd-numbered partials.

[2] The Bohlen-Pierce clarinet project was initiated by TranSpectra member Stephen Fox and four of the new clarinets have been built to date.

### C. *LilyPond*

A number of score editors were auditioned for the project and these included: Sibelius, Finale, and MuseScore. Each of these editors had characteristics or foibles that impacted negatively on the project. It must be said that MuseScore proved to be quite useful as it has the ability to export LilyPond notation files. It must be said that these do contain MuseScore formatting, though the extraction of the LilyPond code containing the raw note data is a simple enough matter. Ultimately LilyPond was chosen as the notation editor for the project as it contains a number of attractive features. It is open-source, capable of hosting bespoke rendered graphics, and has an impressive engraving quality.

Since the scale was different from 12-TET, it was decided that unique clef glyphs would take the place of the usual clef signs. LilyPond has the ability to render customisable graphics as it can host the PostScript graphics programming language internally[3]. This allows the user to define graphics from scratch by using PostScript code inline in the score code. In this way the clef glyphs shown in Fig. N were created. The ranges are traditional; there is a 'high' or soprano voice, a 'middle' or alto/tenor voice, and a 'bass' voice which can extend down to the basso range. The shape note-head glyphs are used in the traditional way – by assigning them to harmonic functions. This is accomplished in LilyPond by the use of an override function and this results in the engraving shown in Fig. 1.[4] This score shows a scale run with Shape notehead glyphs identifying the scale steps with JI intervals 1/1, 5/3 and 7/3.

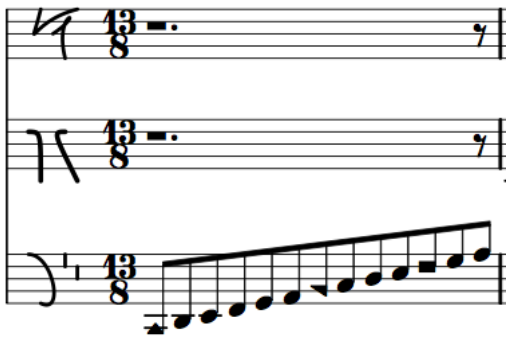

Figure 1. B-P scale on modified system showing Shape noteheads

## III. THE CONTROLLER KEYBOARD

In order to experiment with the B-P scale in a setting which involves improvisation, it is essential to have a physical interface for note input. Two B-P interfaces have been created for this project to date: one is set up in Delta mode, the other in Lambda mode. These keyboards have been repurposed from standard Roland MIDI controller keyboards: all of the keys were removed and rearranged so that the layouts matched the original templates proposed by Bohlen in his paper [3]. In each case, diatonic notes (of the mode in question) are mapped to the white keys and chromatic notes are mapped to the reconfigured black keys. The keyboards provide a 'front end' for an additive synthesis instrument created in Pure Data. This instrument, which is described in the next section, hosts all of the voice generation functions, the tuning conversions, and the MIDI crosspatches in one patch.

[3] PostScript is a page description language. It makes vector graphic output possible – scalable, high-resolution graphics.

[4] It was found that only a limited number of the wide range of shape-note graphics could be applied when using the override function. There were still enough available to complete a convincing score.

## IV. Voice and Tuning Implementation

### A. The Pure Data Synthesiser

The tuning implementation and voice generation portion of the system was implemented in Pure Data. This package was chosen because it is open-source software, and because it runs relatively seamlessly on a number of platforms including Linux. The messages sent out by the controller keyboards are interpreted in the Pure Date synthesis package. A number of functions are carried out by this part of the system and this includes: the maps of the keyboards and the crosspatches to compensate for any repositioning that occurred as part of the repurposing; the 'tuning math' for creating the microtonal scales (in this case the two different modes of B-P scale – Lambda and Delta modes); switching logic for selecting the tuning type (equal-tempered or just intonation) and the mode type (Lambda or Delta); voice generation blocks for creating timbres with fully adjustable partials (frequency and amplitude) and partial envelopes; voice allocation patches for realising polyphony; and a relatively simple front panel user interface (UI) with controls for the performer. The panel is traditional in nature, with associated functions grouped onto sub-panels affixed to the main panel. The main panel is designed to be easy to reconfigure onsite (by a technician), so that the UI can be updated quickly in response to user feedback and comments. The user has control over the customary parameters such as volume and timbre. There are also controls for the partial envelopes – and a series of 'timbre presets'; these are pre-assigned spectrum values that can be loaded by actuating the preset controls.

## V. Conclusion

Taking into account that the goal of the three discoverers of the B-P scale was an tonal alternative to the avant-garde 12-TET output of the time: a non 12-EDO musical system that was capable of supporting an alternate system of harmony, perhaps there will be reservations about restricting the scope of the scale by employing oversimplified notation schemes. It could be that a system incorporating key signatures implemented in a score editor is an end result more true to the wishes of the B-P progenitors. Yet the benefits of accidental-free notation clarified with shape note heads are clear: ease of performance, low familiarisation time, and rapid acquisition of B-P sightreading skills. The system is designed to facilitate rapid acclimatisation with the sound-world of Bohlen-Pierce scales (and perhaps, of microtonal scales in general); a 'thin-sliced' introduction to an intriguing and highly musical scale. It would be entirely appropriate for recently recruited microtonal acolytes to continue to provide feedback into the system so that improvements could be incorporated.

[1] Miles Leigh Skinner, '*Towards a quarter-tone syntax: Analyses of selected works by Blackwood, Haba, Ives and Wyschnegradsky*,' (SUNY Buffalo: 2007)

[2] Erhard Karkoschka, '*Notation in New Music'*, (Universal Edition, Austria, 1972)

[3] Heinz Bohlen, '13 Tonstufen in der Duodezime,' *Acustica*, Vol. 39 no. 2, Jan. 1978, pp. 76-78

[4] Kees van Prooijen, 'A Theory of Equal-Tempered Scales' in *Interface*, vol. 7 no.1, June 1978, pp. 45-56

[5] Max V. Matthews, L.A. Roberts and John R. Pierce, 'Four new scales based on nonsuccessive-integer-ratio chords,' *J. Acoust. Soc. Am.*, vol 75, Issue S1, p. S10 (1984).

[6] TransSpectra, http://www.transpectra.org/scale_info.html [accessed 03 November 2011]

[7] Miller Puckette, '*The Theory and Technique of Electronic Music,*' (Berkeley, CA, World Scientific Publishing, 2007)