The general rank one matrix bispectral operators

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We prove a very general theorem establishing the bispectrality of noncommutative Darboux transformations. It has a wide range of applications that establish bispectrality of such transformations for differential operators with values in all noncommutative algebras. All known bispectral Darboux transformations are special cases of the theorem. Using the methods of the spectral theory of matrix polynomials, we explicitly classify the set of bispectral Darboux transformations from rank one differential operators with values in matrix algebras. New examples of bispectral operators are presented. In particular they include bispectral superdifferential operators.